1981-1983

UNIVERSITY OF LOWELL

GRADUATE SCHOOL CATALOGUE

Graduate School Catalogue
University of Lowell

The University of Lowell is an Affirmative Action/Equal Opportunity University and does not discriminate on the basis of sex or handicap status in its educational programs, activities, or employment policies as required by Title IX of the Education Amendments of 1972 and Section 504 of the Rehabilitation Act of 1973, as amended.

This catalogue was prepared well in advance of its effective date, therefore it is possible that the course descriptions may vary to some extent from actual course content due to advancements in the discipline or other academic decision-making process. The descriptions that are given, therefore, are not provided in the nature of a contractual obligation.

REPORTING CORRECT ADDRESS

It is of importance that students report address changes on special forms provided for that purpose in the Graduate School Office. All correspondence, grades, etc., will be sent to the latest mailing address on file.

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UNIVERSITY OF LOWELL

Lowell, Massachusetts

THE GRADUATE SCHOOL 1981-1983 CATALOGUE

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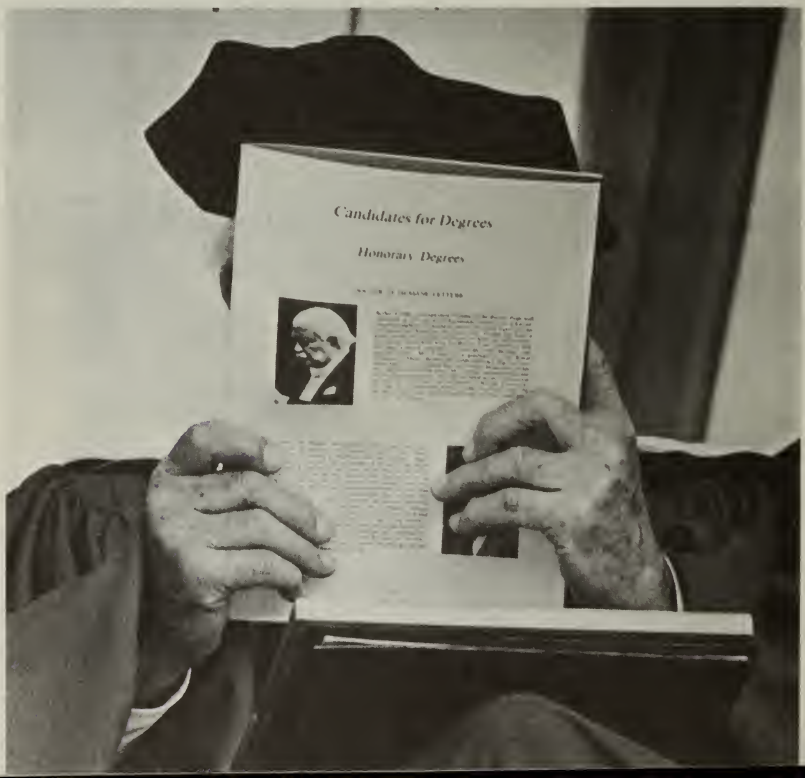

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UNIVERSITY OF LOWELL

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Lowell, Mass. 01854
Telephone: 617-452-5000

Established in 1975 by a merger of
Lowell Technological Institute, established 1895
and
Lowell State College, established 1894

ACCREDITATION AND PROFESSIONAL MEMBERSHIPS

The University of Lowell, as the successor of Lowell State College and Lowell Technological Institute, is an accredited member of the New England Association of Schools and Colleges. Professional programs are also accredited by the following national associations:

American Chemical Society
American Assembly of Collegiate Schools of Business
Accreditation Board for Engineering and Technology (Chemical Engineering, Civil Engineering, Electrical Engineering, Energy Engineering, Mechanical Engineering, and Plastics Engineering.
National Accrediting Agency for Clinical Laboratory Sciences
National Association of Schools of Music
National Council for the Accreditation of Teacher Education (Elementary Education, Music Education, and Secondary Education)
National League for Nursing

The University is also a member in good standing of the following associations of higher education:

American Society of Engineering Education
American Association of Colleges for Teacher Education
Association for Gerontology in Higher Education
American Association of Colleges of Nursing
American Council on Education
Association for State Colleges and Universities
College Entrance Examination Board
Council of Graduate Schools in the United States
Interstate Certification Compact
National Association of Summer Sessions
National University Extension Association
New England Board of Higher Education


CUMNOCK HALL

PROGRAMS OFFERED

The University of Lowell Graduate School offers graduate programs in the following areas:

Doctor of Philosophy

Chemistry
Chemistry - Polymer Science and Plastics Engineering
Chemistry - Environmental Studies
Chemistry - Biochemistry
Physics
Physics - Energy Engineering
Physics - Mechanical Engineering
Physics - Radiological Science

Certificate of Advanced Graduate Study

Reading and Language

Master of Arts

Community and Social Psychology

Master of Science

Biological Sciences
Chemical Engineering
Chemistry
Civil Engineering
Computer Engineering
Electrical Engineering
Energy Engineering (Fission, Fusion, Solar, Geothermal)
Environmental Studies
Mathematics
Mathematics - Applied Mathematics Option
Mathematics - Computer Science Option
Mathematics - Mathematics for Teachers Option
Mechanical Engineering
Nursing Practitioner - Gerontological Nursing
Nursing Practitioner - Primary Care Nursing
Paper Engineering
Physics
Plastics Engineering
Polymer Science
Radiological Sciences
Systems Engineering

Master of Education

Curriculum and Instruction
Educational Administration
Reading and Language

Master of Music

Performance
Music Education
Musicology
Music Theory-Composition

Master of Business Administration

History

The University of Lowell was established by Chapter 1175, General Laws of the Commonwealth of Massachusetts, through a merger of Lowell State College and Lowell Technological Institute. These two institutions were established in the last decade of the 19th century as single-purpose institutions and were charged with providing instruction in those theories and practical arts which were most suitable to the teaching profession and the textile industry. Lowell State College was chartered by the General Court of the Commonwealth on January 6, 1894 as a teacher-training institution and was assigned the responsibility for providing "the most thorough knowledge of the branches of learning required to be taught in schools, the best methods of teaching these branches, and right mental training." In 1932, the institution was made a four-year college and was granted the right to confer baccalaureate degrees. In 1960, the college became a multi-purpose institution by initiating non-teaching programs in the liberal arts. During the next decade and a half the college continuously extended its mission and curriculum offerings at both the graduate and undergraduate levels and was authorized to offer degree programs in education, the health professions, the liberal arts, sciences, and music. From the time of its origin in 1895 as a proprietary textile school, Lowell Technological Institute has provided educational programs of an applied and practical nature. "Science and art will be taught," the original prospectus pointed out, "with a view to industrial and commercial application" and for "the purpose of improving any special trade or of introducing new branches of industry." The control of the school was transferred to the commonwealth in 1918, and in 1928 it was granted collegiate status. In 1953, it because a multi-purpose technological institute. During the last decade, the institute phased out its textile curricula, extended its curriculum offerings in engineering and technology, the pure and applied sciences, business administration and industrial management. In 1965, Lowell Technological Institute received authorization to offer degrees through the doctorate level.

The merging of Lowell State College and Lowell Technological Institute has brought together two multi-purpose institutions of differing character and orientation and has made possible the creation of a comprehensive university whose strengths and resources are manifestly greater than those possessed by the two

separate institutions. The University of Lowell's graduate students account for approximately 1500 of the 11,000 students enrolled, and the graduate faculty numbers approximately 200 of 400 members of the University's teaching staff. The combined institutions have organized diversified graduate programs in the fields of Business Administration, Education, Engineering, Nursing, Music, Pure and Applied Sciences and Psychology.

Purpose of the University

Recognizing its responsibility as a publicly supported institution of higher education, the University of Lowell seeks to discover, integrate, and transmit knowledge to meet the economic, professional, and cultural needs of the Commonwealth. To those ends, the University offers undergraduate and graduate degree programs, in business, education, engineering and technology, nursing, liberal arts, music, and the pure and applied sciences. The University maintains a wide range of continuing-education programs for those individuals who cannot attend classes on a full-time basis because of age, family responsibilities, or economic constraints and for those who seek continuing personal and professional development. The University also provides special business, industrial, health, scientific, and educational seminars and training programs in cooperation with both public and private sectors. Through these educational programs, the University strives to develop individual capacities for rational analysis and effective decision making and to create a basic understanding of our cultural and scientific heritage. Finally, the University has a special mission to continue the positive implementation of Equal Opportunity/Affirmative Action, Title IX, thereby ensuring that all students and employees, and in particular, minorities, veterans, women, and handicapped persons are guaranteed the benefits of a just and equitable system.

Mission of the Graduate School

The mission of the Graduate School at the University of Lowell is to provide a fertile and stimulating environment for teaching, learning, research, dissemination of professional skills, and promotion of the pursuit of knowledge. To this end, the Graduate School encourages the assemblage of scholars, scientists, and artists under whose direction graduate students can pursue advanced studies and carry out research activities. The quality of the Graduate Faculty involved in these programs is the most import-

ant factor in the establishment of excellence and in an endeavor to accomplish the mission of the Graduate School, each professor aspires to be a creative and skillful teacher.

The Graduate School recognizes its responsibility as a publicly-supported institution of higher education to develop in students competence and motivation to work toward the realization of individual and community potential. The central purpose of the University is to enhance the quality of life in our society and the role of the Graduate School in this overall objective is to provide as broad an education as possible along with professional expertise.

Location

The University of Lowell is located 25 miles northwest of Boston and is situated on the northwestern periphery of the City of Lowell. The two major campuses lie on opposite sides of the Merrimack River, the power source which gave rise to America's first industrial city. The North Campus is the primary location for the Sciences, Engineering and Management and is a short distance across the river from the Research Foundation and Fox Student Union Building. The latter facility is the key center for student campus life, including many activities accessible to graduate students. The South Campus is situated on a bend of the Merrimack River approximately one mile upstream from the North Campus and occupies an elevated site midway between the mouths of the historic Middlesex and Pawtucket Canals. The Colleges of Education, Liberal Arts, Music and Health Professions are located on the South Campus. The physical area of the University campuses includes 29 buildings on 105 acres of land. The campuses are easily accessible from US Route 3 and Interstate 495, by train from Boston (Massachusetts Bay Transportation Authority), and by local and interstate bus lines (Massachusetts Bay Transporation Authority, Continental, and Vermont Transit).

In addition to being the home of the University, Lowell is a city rich in heritage. Due to its prime location on the Merrimack River it became the first great industrial city in the United States. Different immigrant groups migrated to Lowell to work in the mills that were built along the river. Today, the descendants of these varied ethnic groups make up much of Lowell's population of 94,000. The city recently has been designated as the site for an Urban National Park, and in its construction Lowell's industrial and multi-ethnic history will be reflected.

UNIVERSITY LIBRARIES

The University libraries consist of the Alumni/Lydon Library (North Campus) and the O'Leary Library (South Campus). The O'Leary Library has holdings in the humanities, social sciences, allied health and music. The Alumni/Lydon Library specializes in materials in science, technology and business. The special collections area of the University libraries include rare books and artifacts relating to the history of the City of Lowell. The Reference department provides ILL services, computer and manual literature searches, special bibliographic instruction and ready reference service. The University libraries have also been designated as a United States Government depository for unclassified documents. Information and handbooks about the University libraries are available at the Circulation and Reference desks of the libraries.

Media Services, a division of the University libraries, provides presentation, production and consultation related to instructional media.

The O'Leary Library incorporates a media center that can accomodate over 230 students in five instructional and presentation areas. The Alumni/Lydon Library can accomodate over 140 students in two instructional and presentation areas. The combined collection includes 450 films and video tapes, over 4000 scores and over 5000 records and tapes of classical, jazz, folk, rock and other musical forms.

Media professionals are available on each campus to assist with media and music listening needs at the University. For further information and assistance, call or write the University libraries.

Computer Center

The University Computer Center provides the facilities for both the academic and administrative computing needs of the University. The central facility consists of a CDC CYBER-71 Computer System with a full complement of peripherals and resources to support batch, remote batch, and interactive time-sharing environments. The computer system supports an interactive environment, providing facilities for teaching and research in modern techniques of engineering process control systems, engineering graphic design systems, on-line nuclear data acquisition, nuclear reactor safety and control systems, business and industrial management simulation, and other similar applications. The computer system provides direct access to its resources through a network consisting of 100 interactive terminals located throughout the University campus, and 2 Remote Job Entry (RJE) terminals. The CYBER-71 Computer System is provided with 98K words of core memory, 950 million characters of disk storage, 2 magnetic tape transports, 2 fast line printers, 1 fast card punch, 1 fast card reader, and a communications controller with 64 ports. The operating system software includes Assembler language, FORTRAN, COBOL, BASIC, Data Base Management System, and a library of application programs. The Computer Center is located in Olsen Hall on the North Campus.

The Computer Center also supports a microcomputer laboratory provided with 11 Data General Micronova computers. This laboratory provides hands-on experience with operating systems.

Durgin Hall

In 1976 the University opened this major complex for the performance, practice and teaching of music. Beautifully situated on the banks of the Merrimack River (South Campus), Durgin Hall contains a concert hall with seating for over one thousand and features an acoustical shell on the stage, an orchestra pit which can be raised and lowered, and a lighting console of sufficient flexibility to permit production of any type of concert from chamber music to opera or any type of theatre from musicals to classical drama. The recital hall, which seats two hundred fifty, is ideal for student and faculty recitals and houses a Schlicker tracker organ of eleven ranks. Seventy-two practice cubicles, twelve classrooms and sixteen teaching studios, a recording studio, two electronic piano laboratories and an electronic music laboratory provide basic facilities to study, teach, and perform.

Energy Center

The University of Lowell Pinanski Energy Center, located on the North Campus, is a modern educational and research facility. The central complex of the Center is a three-story building devoted to research and instruction in various fields of science and engineering. The two major facilities of the Center include a 1 Mw pool type research reactor and a 5.5 Mev Van de Graaff accelerator. The reactor is used for graduate research through activation analysis of various environmental, geologic and industrial process samples, and through studies of radiological particle behavior; it is also used for training and education in the fields of engineering, radiochemistry, radiation protection, and instrumentation, to name a few. The accelerator is used mainly for graduate research in nuclear structure and material engineering, particularly as applied to gathering data for fast breeder reactor design. A solar collector testing facility exists on the roof of the Energy Center and other solar equipment is used in the formal solar engineering courses. Although financed by the Commonwealth mainly to serve the curricula of the University, the facilities are available by arrangement to other Massachusetts colleges and universities, and to industrial firms for a variety of research and educational purposes. The Center is also equipped with an advanced machine shop, and an assortment of teaching and research laboratories.

Research Foundation

The Research Foundation (North Campus) was established in 1950 as a not-for-profit organization which operates from income derived from research funded by private industry, foundations, and government agencies. The foundation contains major support facilities for faculty and student research projects, and provides a mechanism for the administration and fiscal management of all academic grants and contracts. Two auxiliary enterprises, the Meteorology and Testing Divisions, help to defray the overhead costs of the facility. Meteorology services are provided to assist industry and government through the repair and calibration of electronic test equipment with traceability to the National Bureau of Standards. This service is available from the Foundation or its fully equipped mobile laboratory. Also based at the Foundation are the Center for Atmospheric Research and the Center for Tropical Diseases Research.

As part of its close cooperation with the University, the Research Foundation employs both graduate and undergraduate stu-

dents from the University on a part-time basis. These students gain practical experience which often becomes part of an advanced degree program. In addition to the research which is carried out on campus, research projects also have been conducted in Thailand, Belgium, Greece, Italy, Germany, Algeria and other parts of the world where the University is becoming known for its significant expertise. For further information, contact Dr. Susan A. Goodwin, Acting Dean of Research and Director, University of Lowell Research Foundation, 450 Aiken Street, Lowell, Massachusetts 01854, telephone (617) 458-2508.

Continuing Education

One of the most active segments of the University is the Division of Continuing Education. Through this branch, the Graduate School administers various degree programs in Plastics, Mathematics, Engineering and Business Administration. Through the auspices of Continuing Education many graduate courses are offered in conjunction with Graduate School programs in Music, Engineering, Education, Nursing, and the Sciences. In addition to credit offerings, non-credit courses, workshops, conferences, and special projects are conducted during various times in the day and evening. All Continuing Education programs are administered on a self-supporting basis at no cost to the Commonwealth of Massachusetts. Detailed information is available upon request from the Division of Continuing Education of the University of Lowell.

Summer School

The Division of Continuing Education administers a wide variety of Summer School offerings from May through August during the morning, afternoon, and evening, with class meetings scheduled daily or several days a week to effect maximum availability to the greatest number of students. The Graduate School is represented amply in these Summer Sessions by courses in all areas in which there are graduate programs, and by special projects and workshops. All offerings are open to matriculated graduate students and to qualified non-degree and provisional students. For detailed information, brochures are available upon request from the Graduate School. The University of Lowell Summer School is a member of the National Association of Summer Schools (NASS).

Student Services

Housing

The Graduate School has four annex units for year-round residence of graduate students. The cost of single room occupancy is presently $1140 per year. This includes kitchen and cooking facilities.

Married student housing is also available about a ten-minute walk from the North Campus. One and two-bedroom apartments are available at a cost of $270/mo and $295/mo repsectively. This includes a refrigerator, stove, dishwasher and air conditioner, and cost of all utilities.

Because of the great demand on the limited resources available, the above facilities can be rented only on a first-come, first-served basis. Interested students should fill out an application at the Graduate School as early as possible.

Other housing arrangements may be made by obtaining a list of apartments and rooms for rent from the University Housing Office. The University does not sanction or otherwise endorse any housing off the campus, and accepts no responsibility for student residences other than University-supervised facilities. For further information concerning University housing, call or write the Graduate School Office.

Health Services

The University maintains health service facilities on both campuses for the convenience of students. The Health Service Office on the North Campus is located at 30 Standish Street and is staffed by a Director Nurse Practitioner and one registered nurse from 8:00 A.M. to 4:30 P.M., Monday through Friday. The Health Service Office on the South Campus is located in Mahoney Hall and is staffed by one registered nurse from 8:00 A.M. to 11:30 A.M., Monday through Friday.* A physician is available at the North Campus Health Facility on a part-time basis. In case of an emergency, however, medical care is available on a 24-hour basis at the three local hospitals.

*Second R.N. reports for duty at North Campus Health Service 1:30 P.M. to 4:30 P.M., Monday through Friday.

Graduate Student Association

The purpose of the Graduate Student Association is to enhance the academic, social, and economic advancement of all graduate students, to represent the graduate student body in University affairs, to establish closer interdepartmental relations among graduate students, faculty, and the administration, and to promote the

common interests and better communication among graduate students and with other components of the University community. All graduate students who pay the Graduate Activity fee are members of this organization. All Colleges offering graduate programs are represented in its governing bodies.

Veterans

The University of Lowell is approved for Veterans Administration benefits. Eligible veterans should obtain the necessary application from the Veterans Administration and present it to the Graduate School Office at or before registration. Veterans Administration regulations state that a veteran must be working toward an advanced degree in order to be eligible for benefits. We cannot certify a veteran for individual courses.

All recipients of veterans' benefits are required to certify attendance each month by signing a list available in the Graduate School Office. Failure to do so will be reported to the Veterans Administration at the end of the month.

University Fees* Academic 1981-1982

Graduate School

Tuition (credit hour)	$ 40.00 (Fall 1981) (in state)
	$ 46.00 (Spring 1982) (in state)
up to maximum of (per semester)	$ 477.00 (Fall 1981) (in state)
(per semester)	$ 542.00 (Spring 1982) (in state)
(credit hour)	$ 119.00 (Fall 1981) (out of state)
	$ 135.00 (Spring 1982) (out of state)
up to maximum of (per semester)	$1418.00 (Fall 1981) (out of state)
(per semester)	$1613 (Spring 1982) (out of state)
Audit (credit hour)	$ 27.00 (in state)
	$ 78.50 (out of state)
Continued Advisement	$ 10.00
Late registration fee	$ 20.00
Change of Registration fee	$ 5.00 per transaction
Registration fee	$ 5.00
Student Union fee	$ 25.00 (full time)**
	$ 12.50 (part time)***
Student Activity fee	$ 15.00 (full time)
	$ 10.00 (part time)
Academic Services fee	$ 35.00 (full time)
Commencement fee	$ 15.00
Dorm charges	$1140/calendar year
Married Student housing	$295/month (2 bedroom)
	$270/month (1 bedroom)
Laboratory fee	$ 20.00
Transcript fee	$ 1.00
International Student Processing fee (Charged only once)	$ 25.00

Continuing Education

Registration fee	$ 5.00
Tuition (credit hour)	$ 50.00
Audit (credit hour)	$ 35.00
Late registration fee	$ 10.00
Commencement fee	$ 15.00
Laboratory fee (where applicable)	$ 20.00
Continued Advisement	$ 10.00

*The fees and tuition charges are effective for September, 1981 and are subject to change without notice by the Board of Trustees.

**Full time refers to students registered for 8 or more credits per semester (Ph.D. students registered for research will be considered full time regardless of the number of dissertation credits for which they register.)

***Part time refers to students registered for fewer than 8 credits per semester.

The division of Continuing Education reserves the right to establish fees for special conferences, workshops, non-credit offerings, and the like.

ADMISSIONS

Admission requirements. Admission requirements for graduate study in the University are as follows: (1) a baccalaureate degree or its equivalent from an accredited college or university, (2) a satisfactory scholastic average to demonstrate that the applicant has had adequate preparation for the field in which graduate studies are to be undertaken, (3) a satisfactory score on any appropriate entrance examination required for admission by the program or department to which admission is sought; unless otherwise stated the required examination is the GRE Aptitude, and (4) additional requirements as may be established by individual programs such as personal interviews, auditions, or other departmental requirements. Refer to individual departmental sections for more specific information.

Departmental requirements. The rules, regulations, and policies delineated by the Graduate School constitute only the minimum requirements for admission, retention, and graduation. Each department may have additional requirements mandated by the unique nature of the various programs. It is the responsibility of the graduate student to be aware of the minimum requirements of the Graduate School and, in addition, to observe the special requirements of the particular program in which he/she is enrolled.

Application procedure. Application forms and materials may be obtained from the University of Lowell, Graduate School Office, Lowell, Massachusetts 01854. A non-refundable application fee of $10 for Massachusetts residents ($25 for non-residents) must accompany the application. Each applicant must file the following documents: (1) a completed application form, (2) an official transcript of all undergraduate and graduate records sent directly to the Graduate School by the institution which the applicant attended, (3) three letters of recommendation sent directly to the Graduate School by persons qualified to judge the ability of the applicant to carry on graduate work and research, (4) scholastic test scores specified for various degree programs at the University (see individual departmental requirements), and (5) the "Test of English as a Foreign Language" (TOEFL) for students from countries where English is not the national language. If the TOEFL bulletin cannot be obtained locally, students should write well in advance to: Test of Engish as a Foreign Language, Box 899, Princeton, N.J. 08540, U.S.A.

Application deadline. Completed applications, including all required documents, should be received on or before April 1 for candidates who seek admission for the subsequent summer or fall semester, and on or before November 1 for candidates for the subsequent spring semester.

Types of admission. Students may be admitted to graduate study at the University of Lowell under the following classifications:

1. **Matriculated status:** Students who have met all requirements for admission to a degree program and who have been recommended by the department in which they propose to study as a degree candidate.

2. **Provisional status:** Students who have not met fully the requirements stipulated by the program or Graduate School may be admitted as prospective candidates for a degree on a provisional basis. Such students must have as their initial objective the removal of all deficiencies and their advancement to matriculated status. In order to change status from provisional to matriculated, a student must file, with supporting documentation, the appropriate Academic Petition form obtainable in the Graduate School Office.

Non-degree status: Students without advanced degree objectives may be admitted to take courses on the basis of non-degree status. Such students are not eligible to receive credit toward a degree unless they file a formal application and are then admitted as matriculated students. Upon admission to matriculated status, these students must file an Academic Petition form to have any credits earned previously considered toward an advanced degree; no more than 12 credits earned as a non-degree student may be transferred to a degree program. Students in this category must submit a transcript showing the conferral of a bachelor's degree in order to receive course grades.

Transfer credit. Courses completed elsewhere within five years prior to the date of admission to a graduate degree program at the University of Lowell may be considered for transfer in accordance with the following regulations:

1. A maximum of 10 graduate credits earned with a grade of B or better may be transferred to a master's degree (see individual programs for specific numbers of credits transferrable) and up to 22 credits for a doctoral degree with the appropriate approval.
2. An official transcript and description of the course(s) must be submitted with the written request.
3. The courses presented must be from an accredited institution authorized to grant graduate degrees.
4. The courses presented must not have been used in earning another degree; however, master's degree credits may decrease Ph.D. maximum credit requirements.
5. The courses presented must be appropriate to the degree program for which the applicant is applying.
6. Transfer credit may not be granted for research seminars, clinical courses, practicums, internships, or special projects.
7. Students who wish to transfer credit must file, within the first semester of matriculation, the Academic Petition Form obtainable in the Graduate School Office.

Graduate Advising

An entering graduate student is assigned an adviser as soon as possible after his/her arrival on campus. This adviser is selected by the Graduate Committee of the department in which the student is enrolled; he/she will provide advice and academic counseling relative to the student's degree program, including the following:

1. Help design and then approve the student's complete program leading to an advanced degree.
2. Recommend to the coordinator of the program course credits from within and without the University for transfer into the student's degree program.
3. Approve the procedure by which the student intends to satisfy the language requirement (if any).
4. Arrange for the qualifying examination for the student who is applying for admission to a doctoral program.
5. Meet regularly with the student to determine his/her progress toward the degree objective and to help solve any problem that may arise.
6. Report on the student's progress to the coordinator of the program.

Thesis and Dissertation Committees.

As soon as a student has chosen an area of research or a project, a Thesis Committee for the master's degree candidate or a Dissertation Committee for the doctoral candidate is selected by the Graduate Committee of the appropriate department, subject to the approval of the dean of the Graduate School. The number and nature of the committee members depend on the scope of the thesis, project or dissertation, but one member of each committee will be the student's major adviser (in many cases the student's original adviser). The Dissertation Committee shall consist of at least three members, two of whom shall be from the student's major department. The responsibilities of the Thesis and Dissertation Committee shall be to:

1. Approve the research topic.
2. Supervise the progress of the thesis or dissertation (major adviser only).
3. Arrange for the oral defense of the thesis or dissertation.
4. Report the fulfillment of all thesis, project, and dissertation requirements to the Graduate Committee.

New England Regional Student Program. The University participates in this reciprocal program in which qualified and legal residents of New England may attend the Graduate School and pay in-state tuition charges, plus 25%. Applicants are considered for unique and distinctive graduate level studies not available at their home state university. Full details are available from the New England Board of Higher Education, 68 Walnut Road, Wenham, Massachusetts 01984 or at the University of Lowell Graduate School Office.

Refund Policy

Full-Time students (registered for 8 or more credits) are eligible for tuition refunds (no fees are refundable) only if they withdraw from the University in good standing. Such students must fill out the withdrawal form obtainable in the Graduate Office. Tuition refunds are granted in accordance with the following schedule:

No. of weeks		*Refund*
At least	*But less than*	*Rate*
0	2	80%
2	3	60%
3	4	40%
4	5	20%
5 and over		None

Part-time students (registered for fewer than 8 credits) are eligible for tuition refunds according to the following schedule if they withdraw officially from one or more courses:

Before the first class 100%
After the first week but before the second. 80%
After the second week but before the third 60%
After the third week . . . . . None

Students enrolled under the Continuing Education program are eligible for tuition refunds according to the following schedule if they withdraw officially from one or more courses:

Before the first class 100%
After the first week but before the second. 50%
After the second week . . . . . None

Insurance. Graduate students are required to purchase accident insurance. The present rate is $12.00 per academic year. Additional medical-surgical insurance is also available on an optional basis. Waiver of the accident insurance is possible with proof of self-insurance. All foreign students are strongly urged to take the additional medical insurance.

Thesis. Every graduate student who completes a thesis is required to bear the cost of microfilming and binding at least three copies of the thesis for the University's files in accordance with the following schedule:

Binding fee (per copy)	$7.50
Microfilm fee (M.S.)	20.00
Microfilm fee (Ph.D.)	30.00

Graduate students who have registered for the number of thesis credits required for the degree but who in order to complete their thesis must do further work requiring the use of laboratory facilities, must register for Research Participation and pay a tuition charge for a minimum of 3 credits. Graduate students who have completed all the requirements except the writing and defense of a thesis and do not need to carry out further laboratory work must register for 00.601 Continued Advisement and pay a registration fee per semester.

Financial Aid. Financial need will be determined after the student has filed the FAF (Financial Aid Form) or GAPSFAS (Graduate and Professional School Financial Aid Service) available in the Financial Aid Office, with College Scholarship Service, Princeton, New Jersey. The major source of financial aid recommended to students is the Guaranteed Student Loan Program (also known as HELP loans). These loans are obtained through local banks and the student may borrow up to $5000 at a low interest rate per year for graduate work. Interest rates, repayment schedule, and eligibility for these loans may be obtained from the Financial Aid Office or your participating lending institution.

The college-based financial aid available at the University of Lowell is the National Direct Student Loan, and the College Work-Study Program. To be considered for these programs, students must complete and return the University of Lowell Financial Aid Forms to the Director of Financial Aid at the University. For more information, students should call or write the Director of Financial Aid.

Assistantships and Fellowships

Assistantships. A limited number of teaching assistantships are available for qualified students. These are administered by the Graduate School and the student's department. A student who is to receive an assistantship will be notified and sent a contract by the department. Stipends vary, and the contract will be for the academic year. Reappointments in succeeding years are contingent upon satisfactory performance of duties as well as academic achievement. Tuition is waived for all full-time graduate assistantships.

Fellowships. Fellowships generally are available only for advanced graduate students and through special arrangement with individual research advisers. In some cases, such fellowships may be made availabe to first-year graduate students. Full-time fellowships usually include tuition waivers.

Summer research fellowships. Summer research fellowships generally are available from the Research Council. These grants are used to help support graduate students carrying out their thesis research during the summer months. In order to qualify for this support, students write a research proposal which must be approved by a select screening committee of the Research Council. The amount of this support varies, depending upon the funds available.

Students who wish to be considered for fellowships or assistantships should have their completed Graduate School application material, including transcripts and letters of reference, sent to the dean of the Graduate School no later than February 1 to be considered for the fall semester, and September 1 to be considered for the spring semester. All queries concerning assistantships and fellowships should be directed to the graduate program coordinator.

Continuous registration of graduate students. Matriculated students must register each fall and spring until their program of studies is complete and the degree has been earned. Graduate students who plan to receive an advanced degree in October, however, must register for the previous Summer Session in order to maintain continuous matriculation. If for any reason a student is not registered for a course (because of leave of absence or because all course work except the thesis is complete) he/she must register for 00.601 (Continued Advisement) in order to maintain continuous matriculation. Master's degree candidates may register for 00.601 for not more than one academic year, doctoral candidates for not more than three academic years. A student who fails to maintain continuous matriculation loses his/her status as a degree candidate and must reapply to the Graduate School for readmission and for renewal of candidacy.

Degree requirements for the master's degrees must be completed within a five-year period, and for the doctorate degree within an eight-year period from admission as a matriculated student.

Course numbering system

400-499	Undergraduate courses taken for graduate credit with permission of adviser
500-599	Graduate credit
600-up	Graduate credit: graduate students only.

Academic grades. The grading system uses grades A, AB, B,BC,C, and F with the numerical equivalents of 4.0, 3.5, 3.0, 2.5, 2.0, and 0. The following special grades are also used: I (Incomplete), S (Satisfactory, B or better), U (Unsatisfactory), AU (Audit), W (Withdrawal from a course or from the University), and PR (In progress for courses in Research and Thesis). Candidates registering for research will do so in 3-credit multiples each semester up to the total number recommended and students registering for seminar will register for 1-credit multiples each semester. No graduate degree will be awarded to a student whose cumulative average for course work is below 3.0.

Incomplete. If, because of circumstances beyond a student's control, he/she is unable to meet all the requirements of the course by the end of that semester, the grade of I (Incomplete) may be given. The award of this grade requires an understanding between the instructor and the student concerning the completion of course work. The maximum time limit for submission of all course

work necessary for removal of an Incomplete is the last day of classes of the next semester following the semester (or Summer Session) in which the grade was received. After that time, an unchanged grade of Incomplete is changed automatically to F. An extension of the time limit is possible but must be approved, prior to the expiration date stated above, by the instructor and the dean of the College through which the course is offered. Written approval indicating the new time limit must be filed with the dean of the Graduate School.

Audit. A graduate student may, upon approval of the adviser and the instructor, register for a course on an audit basis. Audit students are not required to take tests or the final examination. A change in registration from audit to credit or vice versa must be effected during the add/drop period. Under no circumstances can a course taken for audit be given credit at a later date.

Withdrawal. Students finding it necessary to withdraw from a course must do so with departmental approval in the time specified in the academic calendar. The student's permanent record will indicate a grade of W for the course(s) from which he/she has withdrawn unless the withdrawal has taken place in the first 10 days of the semester, during which time no record will be kept. Students who wish to withdraw from the University must obtain a withdrawal clearance form from the Graduate School and have it completed in triplicate. This procedure insures that the student's academic and financial obligations are cleared before he/she leaves the University. For students officially withdrawing from the University, the permanent record will indicate a grade of W if approved by the individual instructors of courses being pursued at the time of withdrawal. If the student fails to follow the official withdrawal procedure and does not withdraw in good standing, official transcripts of the student's academic record will not be issued and the student will not be permitted readmission to the Graduate School except under extenuating circumstances. A student's file will remain active up to two years after withdrawal. At any time during this period, students may request readmission by writing to the Graduate School. After two years, students must file a new application in order to be readmitted to the Graduate School.

In Progress. For courses in Research and Thesis, the student is assigned the grade PR (In progress). This grade will be indicated on the student's record each semester until the research or thesis is completed. During the semester when the work is completed, the grade of S or U will be given.

Graduate credit for undergraduate courses. Courses at the 400 level are designed for seniors but under certain circumstances may be taken by graduate students for graduate credit. The student is required to file a Special Petition form obtainable in the Graduate School, at the time of registration. If a graduate student takes certain undergraduate courses to make up background deficiencies, the course credit hours are not used as part of the graduate degree program. A maximum of 6 credits of 400 level courses may be used for graduate credit.

Undergraduate credit for graduate courses. Qualified upperclassmen who wish to take any course at the 500 level for undergraduate credit must obtain the necessary approval by means of a Special Petition form. The grade received in any such course is used in calculating the student's cumulative grade point index. Such students may not earn graduate credit until they have completed all requirements for the bachelor's degree.

Non-Degree Credit. Non-Degree Students who apply for matriculated status as degree candidates may transfer no more than 12 credits earned in the non-degree classification. Departments may limit the number of transferrable credits still further.

Changes in registration. Courses may be added, dropped, or changed from audit to credit by completing the appropriate add/drop forms and obtaining the permission of the student's adviser. This may be done during 10 academic days from the beginning of the semester and courses dropped will not appear on the student's permanent record. After this period, no new courses may be added and no course may be changed from audit to credit. Students wishing to drop courses may do so until the week before classes end (see academic calendar) and these courses will appear as W on the student's record. All changes in registration must be brought to the Graduate School Office for processing or they will not appear on the student's record.

Change of major. In order for a student to change major or area of concentration, he/she must have an Academic Petition signed by the coordinator and department chairman of the new and old major. This petition should include the acceptance of the student to the new program, and should indicate the courses and the total number of credits that may be transferred to the student's new degree program.

Transcripts. In order to obtain a transcript, a student must submit his/her name, major, and year attended or graduated to the registrar's office through a written request by mail or by filling out the form in the registrar's office. The first three transcripts obtained are free; there is a charge of one dollar for all additional transcripts. Transcripts given directly to students do not carry the University seal and are not official. The seal is attached when the transcript is mailed directly from the University to the receiving party.

RETENTION POLICY. No more than 6 credits of C and/or BC may be counted toward the master's degree; no more than 9 credits of the same grades may be counted toward the Ph.D. No advanced degree will be awarded any student whose overall cumulative average falls below 3.0. Students earning one C or BC will be reviewed by their adviser and the coordinator of the appropriate program. Students earning two C's or BC's will be reviewed by the Graduate Committee of the appropriate department for such action as a warning, probation, loss of degree candidacy, etc. Those receiving more than two C's and/or BC's or any grade lower than C will be reviewed by the Graduate Committee of the appropriate department for such action as dismissal, probation, loss of degree candidacy, imposition of additional requirements, etc. Action on such students is subject to the approval of the dean of the appropriate College. The dean of the Graduate School may at any time examine the performance of any student not living up to the academic standard expected of graduate students and recommend to the appropriate graduate committee a course of action to remedy the situation. Graduate students dropped for academic reasons may appeal to the graduate committee of the appropriate department or College for a review of the decision. Such students dissatisfied with the appeal decision at this level may appeal ultimately to the dean of the Graduate School.

REQUIREMENTS FOR DEGREE CONFERRAL

General Requirements for the Master's Degree

To be recommended for a master's degree, a candidate must satisfy requirements of the Graduate School and the specific requirements of the College in which he/she is enrolled. The requirements of the Graduate School are given below, and the specific requirements established by the various departments may be found in the section describing the particular programs.

A candidate for the master's degree must:

1. Complete a course of study designed by the department in which he/she is enrolled and approved by the Graduate School. The approved course of study must have a minimum of 30 credit hours of graduate study including, where applicable, a thesis or project in the student's chosen field.

2. Where applicable, complete a master's thesis or a master's project which will consist of scholarly investigation, such as a review, report, synthesis or design in the student's field. The thesis or project must be of the quality expected of graduate study and be approved by the department in which the student is enrolled and by the Graduate School. A thesis reporting the results of research must conform to the format specified in the Thesis Guide, which is available in the Graduate School Office. The only grades given for thesis work are S (satisfactory) U (unsatisfactory) and PR (in progress). Three copies of the thesis abstract or project must be filed in the Graduate School Office.

3. Successfully pass any oral or written examination on his/her complete master's program that the department may require.

4. Earn satisfactory grades in all subjects offered for the degree. The lowest grade acceptable for graduate credit is C, but the overall cumulative average of all courses taken must be at least 3.0.

All undergraduate subjects taken to clear deficiencies in the student's preparation for graduate work, but which are taken during his/her enrollment as a graduate student must be passed with a grade of at least C. However, these courses may not be submitted as part of the course of study leading to the master's degree.

5. Fulfill departmental language requirements.

6. Satisfy all requirements as to tuition, fees, expenses as evidenced by completing and submitting the Advanced Degree Clearance form to the Graduate School Office. At this time the student will be asked to make an appointment for an exit interview at the Graduate School.

COMBINED B.S./M.S. DEGREE PROGRAMS

In order to encourage outstanding undergraduate students to continue their studies toward an advanced degree, several departments have instituted a program of accelerated study which leads to a master's degree. Presently these programs are offered in the following departments: Chemical Engineering, Civil Engineering, Environmental Studies, Electrical Engineering, Energy Engineering, Mechanical Engineering, Plastics Engineering, Biological Sciences and Mathematics.

To be eligible to enter this course of study, the student must file a formal Graduate School application in the junior year. This does not require the student to take a GRE examination. Upon recommendation of the student's adviser, and with the approval of the departmental graduate admissions committee and the dean of the Graduate School, the student may be admitted to graduate study during the senior year. Upon the recommendation of the graduate admissions committee of the department and the approval of the Graduate School dean, the student officially becomes a provisional graduate student in the second semester of the senior year.

The student will then receive a bachelor's degree at the end of the fourth year of study, if all course requirements have been met, and may then be recommended for status as a fully-matriculated student upon recommendation of the departmental admissions committee and approval of the dean of the Graduate School before the start of the fifth year.

Graduate or advanced undergraduate (400 level) courses taken during the senior year may be used for both the graduate and undergraduate degrees up to the amount indicated by each of the individual programs. The total number of credits used for the combined degree must, however, be greater than the minimum number of credits required to obtain an undergraduate degree. As an example, if the student's department requires 132 credits, and the University B.S. requirement is 120 credits, the student may, with approval, transfer up to 12 credits toward the M.S. degree.

As in the regular M.S. program, the department may or may not require a thesis or additional courses, as specified in the specific rules and regulations of the department. The student must also meet all departmental and Graduate School regulations for the M.S. degree.

Students taking full advantage of the combined program ordinarily would be expected to finish the M.S. degree at the end of

the fifth year of study. However, this will depend upon the student's course load and thesis work. The student may be eligible for financial assistance, i.e., fellowships and teaching assistantships, during the fifth year of study, but this may delay completion of the program. See individual Programs in this catalog or consult departmental coordinator for further information.

Doctor of Philosophy Requirements

The degree is conferred upon graduates who have met the following requirements:

1. The successful completion of graduate courses in the major fields. The student's Dissertation Committee and adviser will determine the number of graduate credits which the student must earn, but a program consisting of between 70 and 80 credits, including 24 in research, is considered average.

2. The satisfactory completion of the foreign language requirements specified by the major department.

3. The passing of a comprehensive qualifying examination, oral and written, to be conducted by the major department and to be passed not later than eight months before the completion of the candidate's work. If the student fails the comprehensive examination he/she may, at the discretion of the Dissertation Committee or adviser, be permitted a second and final opportunity.

4. The holding of a Teaching Assistantship for a minimum of two semesters. (This requirement may be waived.)

5. The preparation of a dissertation based upon the results of original research which is satisfactory to the Dissertation Committee and the major department.

6. The passing of a final oral examination conducted by the Dissertation Committee, primarily upon, but not necessarily limited to, the contents of the candidate's dissertation. The examination cannot be scheduled until all members of the Dissertation Committee and the major department have approved the dissertation. The oral examination is to be conducted by the Dissertation Committee, whose membership may be augmented by the nonvoting faculty and representatives of the Graduate School. In order to pass, the candidate may not receive more than one dissenting vote from the members of the Dissertation Committee.

7. The satisfactory completion of the residence requirement. The equivalent of at least one academic year of full-time graduate work must be spent at the University. The requirement for a year in residence may be satisfied only by the student's physical pres-

ence on campus for two consecutive semesters. This may be either a fall-spring sequence or a spring-fall sequence. It cannot be satisfied by a summer session and a semester of the regular school year.

8. The completion of all Ph.D. requirements within eight years after the student's admission as a graduate student. Extension beyond this time may be granted only with the joint approval of the student's Advisory Committee, Department Chairperson, College Dean, and Dean of the Graduate School.

9. The satisfactory completion of all financial obligations (tuition, fees, and expenses) as evidenced by completing and submitting the Advanced Degree Clearance form to the Graduate School Office. At this time the student will be asked to make an appointment for an exit interview at the Graduate School.

10. Full-time faculty of the University of Lowell are not eligible to earn the Ph.D. at this University.

Graduate Foreign Language Requirement

The Graduate School specifies that individual departments establish departmental foreign language requirements for both M.S. and Ph.D. degree candidates according to the levels of competence and overall policy given below. The department will decide the number of foreign languages and the level of competency it wishes to require in each. For purposes of these requirements, a foreign language will be defined as a language other than the student's native tongue and one in which there is a significant body of literature relevant to his/her academic discipline.

The alternative levels of competency which a department may select are:

1. Reading Level: Equivalent to the knowledge required in two to four years of undergraduate study.

2. Journal Level: Knowledge sufficient to understand journals in the language in the student's academic discipline with the aid of a dictionary.

3. No foreign language competency.

A department may select any of these levels or any combination of them for as many languages as it wishes. When a department selects level one, the student's competence will be decided by the Graduate School Foreign Language Test, which is prepared and scored by the Educational Testing Service, Princeton, New Jersey. The passing grade of this level will be specified by the Graduate School Executive Committee. When a department selects level two, the student's competency will be decided by a departmental committee, with the advice and cooperation of the Department of Languages.

A master's degree candidate will be expected to satisfy departmental language requirements before formally submitting his thesis or project proposal, and a doctoral student will be expected to satisfy departmental language requirements prior to being admitted to candidacy.

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Ralph Rieth . . . . . Business Administration
Robert Lynch . . . . . Biological Sciences
Stanley Israel . . . . . Chemistry
Alfred Donatelli . . . . . Chemical Engineering
Nathan Gartner . . . . . Civil Engineering
Anne McParland . . . . . Education
James Powers . . . . . Electrical Engineering
Jose Martin . . . . . Energy Engineering
Charles Ott . . . . . Environmental Studies
Eleanor Shalhoup . . . . . Nursing
Shimshon Berkovits . . . . . Mathematics
Eugene Niemi . . . . . Mechanical Engineering
Willis Traphagan . . . . . Music
Albert Altman . . . . . Physics
Rudolph Deanin . . . . . Plastics
Edward Alexander . . . . . Radiological Sciences
Dean of the Graduate School, ex officio
Associate Dean of the Graduate School, ex officio
Arthur Watterson, Past Chairman, ex officio

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Albert Altman, *Professor, Physics;* Ph.D., University of Maryland.

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Indu Anand, *Assistant Professor, Management;* Ph.D., New York University.

Donald Anderson, *Instructor, Clinical Nursing;* M.S., University of Lowell.

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Harold L. Asch, *Adjunct Professor and Associate Director, Tropical Disease Center Research Foundation;* Ph.D., Rice University.

Mario Aste, *Associate Professor, Languages;* Ph.D. Catholic University.

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Shimshon Berkovits, *Associate Professor, Mathematics;* Ph.D., Northeastern University.

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Gilbert Brown, *Associate Professor, Nuclear Engineering;* Ph.D., Massachusetts Institute of Technology.

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Ingul Ivan Oak, *Assistant Professor, Performance;* M.M., New England Conservatory.

Arnold L. O'Brien, *Associate Professor, Earth Sciences;* Ph.D., Boston University.

John C. O'Callahan, *Associate Professor, Mechanical Engineering;* Ph.D., Northeastern University; P.E.

John Ogasapian, *Professor, Music History and Literature;* Ph.D., Boston University.

William O'Rourke, *Adjunct Assistant Professor;* Ph.D., Boston College.

Stephen A. Orroth, Jr., *Associate Professor, Plastics Engineering;* M.S., Lowell Technological Institute.

Charles R. Ott, *Associate Professor, Civil Engineering;* Ph.D., University of Washington.

Natalo Paella, *Associate Professor, Performance;* M.M., New England Conservatory of Music.

Martin A. Patt, *Assistant Professor, Electrical Engineering;* S.M., Massachusetts Institue of Technology.

Stephen Petrie, *Assistant Professor of Plastics;* Ph.D., University of Connecticut.

William T. Phelan, *Assistant Professor, Educational Sociology;* Ph.D., University of Chicago.

James P. Phelps, *Professor, Nuclear Engineering;* Ph.D., Michigan State University.

James B. Pierce, *Professor, Chemistry;* Ph.D., Case Institute of Technology.

Brenda Pinardi, *Associate Professor, Art;* M.F.A., Rhode Island College of Design.

Clarence J. Pope, *Professor, Plastics Engineering;* M.S., Lowell Technological Institute.

William Pordon, *Associate Professor, Music Education;* M.M., Chicago Conservatory College.

James E. Powers, *Professor, Electrical Engineering;* M.S., Lowell Technological Institute.

Domenic Procopio, *Professor, Music Theory;* Ph.D., Boston University.

Santo J. Pullara, *Professor, Management;* Ph.D., Syracuse University.

David J. Pullen, *Professor, Physics;* D.Phil., Oxford University.

Yash Puri, *Assistant Professor, Management;* D.B.A., Indiana University.

Hak K. Pyo, *Assistant Professor, Economics;* Ph.D., Clark University.

Chong Wah Pyun, *Professor, Chemistry;* Ph.D., Brown University.

Bodo Reinisch, *Professor, Electrical Engineering;* Ph.D., University of Lowell.

Nicholas J. Rencricca, *Associate Professor, Biological Sciences;* Ph.D., Boston College.

Roy Richard II, *Instructor, Mechanical Engineering;* Ph.D., Tufts University.

Ralph A. Rieth, Jr., *Assistant Professor, Management;* Ph.D., University of Massachusetts.

Ezequiel R. Rivera, *Associate Professor, Biological Sciences;* Ph.D., University of Texas.

Kay Roberts, *Assistant Professor, Performance;* M.M., M.M.A., Yale University.

Joseph R. Rocha, Jr., *Associate Professor, Management;* Ph.D., University of Iowa.

H. James Rome, *Assistant Professor, Electrical Engineering;* Ph.D., University of Michigan.

Harry Rubinstein, *Professor, Chemistry;* Ph.D., Purdue University.

Mary Beth Ruskai, *Assistant Professor, Mathematics;* Ph.D., University of Wisconsin.

Joseph C. Salamone, *Professor, Chemistry;* Ph.D., Polytechnic Institute of Brooklyn.

Dominick A. Sama, *Associate Professor, Chemical Engineering;* Sc.D., Massachusetts Institute of Technology.

Ernesto Sanz, *Assistant Professor, Economics;* Ph.D., Boston College.

Samuel P. Sawan, *Assistant Professor, Chemistry;* Ph.D., University of Akron.

Walter A. Schier, *Professor, Physics;* Ph.D., University of Notre Dame.

Roger T. Schinness, *Assistant Professor, History;* Ph.D., State University of New York (Binghamton).

Garfield C. Schmidt, *Associate Professor, Mathematics;* Ph.D., University of New Hampshire.

Nick R. Schott, *Professor, Plastics Engineering;* Ph.D., University of Arizona.

Allie Scruggs, *Professor, Psychology;* Ed.D., Boston University.

Kunnat J. Sebastian, *Associate Professor, Physics;* Ph.D., University of Maryland.

Burton A. Segall, *Associate Professor, Civil Engineering;* Ph.D., New York University.

Manuel Selvin, *Instructor, Electrical Engineering;* M.S., University of Michigan.

Steven Serabian, *Professor, Mechanical Engineering;* M.S., Union College.

John J. Sewell, *Associate Professor, Civil Engineering;* S.B., C.E., Massachusetts Institute of Technology.

Eleanor Shalhoup, *Associate Professor, Nursing;* Ed.D., Boston University.

Irwin A. Shapiro, *Associate Professor, Management;* Ph.D., Clark University.

James R. Sheff, *Associate Professor, Nuclear Engineering;* Ph.D., University of Washington.

Eric Sheldon, *Professor, Physics;* D.Sc., University of London.

G. Dudley Shepard, *Professor, Mechanical Engineering;* Sc.D., Massachusetts Institute of Technology.

Balbir Sihag, *Assistant Professor, Management;* Ph.D., Massachusetts Institute of Technology.

Linda Silka, *Assistant Professor, Psychology;* Ph.D., Kansas University.

Ilze Skare, *Associate Professor, Biological Sciences;* Ph.D., Duke University.

Kenneth W. Skrable, *Professor, Physics;* Ph.D., Rutgers University.

Karl J. Sladek, *Associate Professor, Chemical Engineering;* Sc.D., Massachusetts Institute of Technology.

I. Stuart Smith, *Associate Professor, Music History and Literature;* M.F.A., Brandeis University.

Paul E. Snoonian, *Associate Professor, Economics;* B.S., M.B.A., Northeastern University; M.A., Ph.D., Michigan State University.

Rawn Spearman, *Associate Professor, Music Education;* Ed.D., Columbia University.

Stanley Spiegel, *Assistant Professor, Mathematics;* Ph.D., Harvard University.

Janice Stecchi, *Associate Professor, Health;* Ed.D., Boston University.

Charles A. Steele, Jr., *Instructor, Mathematics;* M.S., Northeastern University.

Richard Stimets, *Assistant Professor, Physics;* Ph.D., Massachusetts Institute of Technology.

Thomas Stone, *Assistant Professor, Chemistry;* Ph.D., Oregon Graduate Center.

Louis C. Tartaglione, *Associate Professor, Civil Engineering;* M.S., University of Connecticut; P.E.

Amad Tayebei, *Associate Professor, Plastics Engineering;* Sc.D., Massachusetts Institute of Technology.

Virginia S. Taylor, *Associate Professor, Mathematics;* Ph.D., Boston College.

Ye-Yung Teng, *Associate Professor, Physics;* Ph.D., University of Maryland.

Charles F. Thompson, *Assistant Professor, Accounting;* M.B.A., Northeastern University; C.P.A., Massachusetts.

Willis Traphagan, *Professor, Performance;* M.M., Boston University.

W. Anne Trenkamp, *Assistant Professor, Music Theory;* Ph.D., Case-Western Reserve University.

David P. Wade, *Associate Professor, Electrical Engineering;* M.S., Northeastern University.

Robert B. Wagner, *Associate Professor, Educational Philosophy;* Ed.D., Harvard University.

John W. Walkinshaw, *Assistant Professor, Chemical Engineering;* Ph.D., University of Manchester (England).

Mary Roth Walsh, *Associate Professor, American Studies and Psychology;* Ph.D., Boston University.

Arthur C. Watterson, Jr., *Professor, Chemistry;* Ph.D., Brown University.

I. Jacob Weinberg, *Professor, Mathematics;* Ph.D., Massachusetts Institute of Technology.

J. Whiston, *Associate Professor, Performance;* M.S., University of Akron.

Robert White, *Assistant Professor, Performance;* A.M. Harvard University.

Joyce W. Williams, *Assistant Professor, Mathematics;* Ph.D., University of Illinois.

Martin Wilner, *Professor, Physics;* Ph.D., Massachusetts Institute of Technology.

Chuen Wong, *Assistant Professor, Physics;* Ph.D., Case Institute of Technology.

Lee-Jun C. Wong, *Assistant Professor, Biological Sciences;* Ph.D., Ohio State University.

Shan S. Wong, *Assistant Professor, Biochemistry;* Ph.D., Ohio State University.

Louis E. Yelle, *Associate Professor, Management;* M.B.A., Northeastern University.

James A. Zeitler, *Instructor, Economics;* B.A., Gannon College.

Yakov Zilberberg, *Instructor, Mechanical Engineering;* M.S., Technical Institute, Odessa, U.S.S.R.

COLLEGE OF EDUCATION

Dean: M. Virginia Biggy, *Professor;* B.S., Ed.M., Ed.D., Boston University.

Chairman of Faculty: Norman F. Benson, *Associate Professor;* B.S., A.M., University of Minnesota; Ed.D., Ball State University.

Graduate Coordinator: Anne M. McParland, *Associate Professor;* B.S., University of Lowell; C.A.S., Harvard University; Ed.M., Ed.D., Boston University.

FACULTY:

Douglas A. Adamson, *Assistant Professor;* A.B., Yale University; M.Div., Episcopal Divinity School; J.D., Ed.D., Harvard University.

John J. Catallozzi, *Associate Professor;* B.S., University of Lowell; Ed.M., Ed.D., Boston University.

Ado Commito, *Assistant Professor;* B.S., Ed.M., Ed.D., Boston University.

Penelope A. Demogenes, *Associate Professor;* B.S., University of Lowell; Ed.M., C.A.G.S., Boston University.

Thomas G. Devine, *Professor;* B.S., M.A., Ed.D., Boston University.

Alice C. Kiernan, *Associate Professor;* B.S., University of Lowell; Ed.M., Boston University.

Dorothy M. Kron, *Adjunct Professor;* B.S., Framingham State College; Ed.M. C.A.G.S., Boston University.

Richard G. Lyons, *Professor;* B.S., Ed.M., Ph.D., Boston University.

Dorothy V. Meyer, *Associate Professor;* A.B., Houghton College; Ed.M., Ed.D., Boston University.

Olive S. Niles, *Distinguished Professor;* B.S., Mt. Holyoke; M.A., Bryn Mawr; Ed.D., Boston University.

Lisanio R. Orlandi, *Adjunct Professor;* B.S., Ed.M., Boston University; Ph.D., Boston College.

William T. Phelan, *Assistant Professor;* A.B., Boston College; A.M., Catholic University; Ph.D., University of Chicago.

Margaret R. Shannon, *Dean* **Emerita** *and Professor;* B.S., University of Lowell; Ed.M., Ed.D., Harvard University.

Robert B. Wagner, *Associate Professor;* B.S., Ohio State University; A.M., Kent State University; Ed.D., Harvard University.

The College of Education offers graduate degree programs which provide sophisticated professional preparation for those who aspire to serve in the role of an educational specialist. The degree programs offered by the Department of Curriculum and Instruction and their fields of specialization are Master of Education (Ed.M.) in:

Curriculum and Instruction
Educational Administration
Reading and Language

A Master of Education leading to initial teacher certification is also offered.

A Certificate of Advanced Graduate Specialization (C.A.G.S.) is offered in selected fields.

The College of Education is organized according to centers of interest for teaching and research. They are:

The Center for Reading and Language, the Center for Administration, Planning and Policy, and the Center for Curriculum and Instruction. In addition, the Office for Field Services is responsible for all the placement of apprentice teachers, field-based course work and experiences, and community relations.

The Faculty of the Centers are responsible for the degree programs appropriate to their areas of expertise. They are regularly concerned with adjustments to the program and new course offerings, as dictated by changes in the theory, knowledge, research and practice in their fields.

ADMISSION TO DEGREE PROGRAMS IN EDUCATION

Application Procedure

Application forms may be obtained by contacting the Graduate School Office, University of Lowell, Lowell, MA 01854. Each applicant must file the following documents:

1. A completed application form.

2 One copy of his/her teaching certificate must be mailed with the completed application form, if applicable.

3. Two official transcripts from each undergraduate college and graduate school which the applicant attended. These official transcripts must be sent to the Graduate Office by the colleges which the applicant attended. *Transcripts or copies thereof sent by the applicant are not official and will not be accepted.*

4. When applying for any Ed.M. program, an official copy of the applicant's scores obtained on the Miller Analogies Test must be mailed directly to the Graduate Office by the institution which administered the test.

5. Letters of recommendation from three persons who are qualified to evaluate the applicant's academic and professional abilities. The forms for such recommendations are contained in the admission brochure.

Upon receipt of the above admission documents, the Graduate School Office will forward them to the College of Education. All decisions on admissions are made by the Graduate Admissions Committee of the College of Education.

Admission Status

Applicants may be admitted to graduate study in Education in one of the following categories: *Matriculated, Provisional, Non-Degree Status.*

Matriculated Status: Applicants who have met all requirements for admission to a degree program in the Department of Curriculum and Instruction and who have been recommended for admission by the Academic Standards and Admissions Committee.

Provisional Status: Applicants who have not met all stated requirements for admission to a degree program in the College of Education but whose record shows promise may be admitted on a provisional basis. Students admitted to provisional status are required to complete nine (9) semester hours of required course work with a cumulative grade-point average of no less than 3.25. The records of students on provisional status will be evaluated at the end of each semester, and upon completion of nine (9) semester hours of required course work, the student will be notified whether he/she qualifies for matriculated status or for termination of his/her enrollment in a degree program. If the student is eligible for *matriculated status*, the appropriate Academic Petition Form will be filed.

Non-Degree Student: All students who register for graduate courses in this university without filing a formal application for admission to a degree program in Education are presumed to be taking graduate courses for reasons other than earning a degree at this university and are classified as Non-Degree Students.

In the event that such a student applies for admission to a degree program in the College of Education, no more than six semester hours credit earned with a grade of *B* or better while enrolled as a non-degree student may be transferred to the degree program. Transfer of such credits must be in accordance with the regulations governing transfer credits in the College of Education. (See below.)

Requirements for Admission

To qualify for admission to a graduate degree program at the Mas-

ter of Education level in the College of Education, an applicant must have:

1. Earned a baccalaureate degree at an accredited college or university;

2. Completed his/her baccalaureate degree program with a scholastic record that gives evidence of ability to do graduate work - no less than 2.75 (on a 4.0 scale);

3. Achieved a score not lower than the 60th percentile on the Miller Analogies Test;

4. Where applicable, qualified for and been granted a teaching certificate by a state certification office;

5. Received approval for admission by the Graduate Admissions Committee in the College of Education.

To qualify for admission to the Certificate of Advanced Graduate Specialization, an applicant must have:

1. Earned a master's degree at an accredited college or university;

2. Completed his/her master's degree program with a cumulative grade point average of no less than 3.0;

3. Received approval for admission by the Graduate Admissions Committee of the College of Education.

Transfer Credit

Courses completed within two years prior to the date of admission as a matriculated student may be considered for transfer in accordance with the following regulations:

1. No more than six semester hours of graduate credit earned with a grade of *B* or better may be transferred from other institutions of higher education;

2. A request for transfer of such credit must be made in writing by the applicant and must be filed with his/her application for admission;

3. An official description of the course(s) must be submitted with the written request;

4. The courses presented must be resident courses completed on the campus of an accredited institution authorized to grant graduate degrees;

5. The courses presented must not have been used in earning another degree;

6. The courses presented must be appropriate to the degree program for which the applicant is applying;

7. Transfer credit may *not* be granted for research seminars, clinical courses, practicums, or internships;

8. The transfer of no more than six semester hours of course credit must be approved by the Graduate Admissions Committee of the College of Education.

Graduate Adviser

A student who accepts admission will be assigned to a faculty adviser in the College of Education. The adviser's responsibility is to (1) provide academic counseling to the student relative to his/her program; (2) approve the program of studies which the student shall present, and also approve all changes in that program; and (3) periodically evaluate the student's academic progress and make recommendations to the Graduate Admissions Committee concerning the student's continuance, dismissal, or recommendation for a degree.

Degree Requirements

Each graduate student is personally responsible for complying with all the rules and regulations of the Graduate School and the College of Education, and for fulfilling all degree requirements.

In order to qualify for a *Master of Education* degree, each candidate must meet the following requirements:

1. Complete a minimum of thirty semester hours of required course work in a specific degree program. Some degree programs have a higher minimum semester hour credit requirement.
2. Complete all course requirements for the degree program at this university. A maximum of six semester hours of course work taken at another accredited institution is the only exception given.
3. Complete satisfactorily the specified internship and/or field practicum under the supervision of a designated faculty member in the College of Education. *This requirement may not be waived.*
4. Complete all course requirements for the degree with a cumulative grade-point average of *B* or better. No additional course credits may be permitted in order to achieve the grade-point average of *B* or better required for the degree.
5. Complete the degree program within five years of the date of notification of admission.

In order to qualify for a *Certificate of Advanced Graduate Study*, each candidate must meet the following requirements:

1. Complete a minimum of thirty semester hours of required course work in the specified certificate program.
2. Complete all course requirements for the certificate program at this university. A maximum of nine semester hours of

course work taken at another accredited institution is the only exception granted.

3. Complete all course requirements for the degree with a cumulative grade-point average of *B* or better. No additional course credits may be permitted in order to achieve the grade-point average of *B* or better required for the degree.

4. Satisfactorily complete a qualifying paper as approved by his/her area faculty committee.

5. Satisfactorily pass an area comprehensive examination.

6. Complete the certificate program within five years of the date of notification of admission.

Master of Education Degree Programs

All candidates for a Master of Education degree are required to complete no less than six semester hours (including Research Methods) of the Humanistic and Behavioral requirements as recommended by the adviser.

Humanistic and Behavioral Requirements

Area I - Research

The course entitled *01-621-Research Methods* or *01-622 Computer Literacy* is required of all candidates for the Ed.M. degree. A prerequisite for admission to 01-621 is satisfactory completion of an undergraduate course in measurement. This prerequisite may also be met by satisfactory completion of the graduate course entitled *01-521 - Tests and Measurement.*

A student with the approval of his/her adviser should select other course work taking into consideration previous study in this field so that he/she may have a broad background in the area of humanistic, psychological and sociological foundations.

Area II - Humanistic Foundations

01-611 Issues in Philosophy of Education
01-612 Contemporary Issues in Education
01-613 Theories of Moral Education

Area III - Psychological Foundations

01-631 Theories of Learning
01-634 Social Psychology in Education
01-635 Individual Assessment Intelligence: Wechsler-Binet

Area IV - Sociological Foundations

01-641 Issues in Sociology of Education
01-642 The Organization of Schools and School Systems
01-643 The Professionalization of Educational Careers

Master of Education - Elementary Education

This degree program in teacher education is designed for those who plan to teach in an elementary school and to achieve initial teacher certification in Elementary Education, Grades 1-6, in Massachusetts.

The program will begin in June 1982

Interested students should file an application for matriculation into this graduate program and should make an appointment to talk with the Dean of the College of Education.

The degree requirements include the following:

I. Completion of these graduate courses at the University of Lowell:

01-601 - Developmental Psychology	- 3 sem. hrs.
01-602 - Measurement and Evaluation	- 3
01-614 - History of American Education	- 3
06-601 - Reading Education: Elementary	- 3
06-602 - Language and Literature Education	- 3
06-603 - Reading Disabilities	- 3
06-623 - Issues in Childrens Literature	-3
04-601 - Mathematics Education	- 3
04-602 - Social Studies & Science Education	- 3
04-603 - Analysis of Teaching	- 3
04-604 - Seminar in Elementary Education	- 3
05-662 - Equal Educational Opportunity	- 3
04-609 - Teaching: Elementary	-12
	48 sem. hrs.

II. Completion of the Elementary Education Fields of Knowledge Certification requirement. These requirements are prerequisites and must have been completed satisfactorily as part of the *baccalaureate degree*. This list is available from the graduate coordinator on request.

III. Completion of the Certification Minor in Communications. With the exception of courses marked with an asterisk (*), these requirements are prerequisites and must have been completed satisfactorily as part of the *baccalaureate degree*.

American Literature	- 3 sem. hrs.
American Literature	- 3
English Literature	- 3
Analysis of Modern English	- 3
06-601 - Reading Education	- 3
06-602 - Language and Literature Education	- 3
	18 sem. hrs.

Semester Schedule

Summer Session I (4 weeks)		
01-601 - Developmental Psychology	3 s.h.	MTWTH 9:00-11:30
01-614 - History American Education	3	MTWTH 12:00-2:30
	6 s.h.	
Summer Session II (4 weeks)		
04-602 - Social Studies & Science Educ.	3 s.h.	MTWTH 9:00-11:30
01-602 - Measurement and Evaluation	3	
	6 s.h.	
Fall Semester		
06-601 - Reading Education: Elementary	3 s.h.	Field-based
06-602 - Language & Literature Educ.	3	Field-based
04-601 - Mathematics Education	3	Field-based
04-603 - Analysis of Teaching	3	Field-based
04-604 - Seminar in Elementary Educ.	3	
05-662 - Equal Educational Opportunity	3	
	18 s.h.	
Spring Semester		
04-609 - Teaching: Elementary	12 s.h.	
06-603 - Reading Disabilities	3	
06-623 - Issues in Children's Literature	3	
	18 s.h.	

Master of Education - Secondary Education: English

This degree program in teacher education is designed for those who plan to teach English in the secondary school and to achieve teacher certification in Secondary Education: English, Grades 9-12. The degree requirements include the following:

I. Completion of these graduate courses at the University of Lowell:

01-601 - Developmental Psychology	- 3 sem. hrs.
01-602 - Measurement and Evaluation	- 3
01-614 - History of American Education	- 3
04-645 - Curriculum Development: Secondary School	- 3
04-615 - Curriculum & Teaching English	- 3
06-605 - Reading Education: Secondary	- 3
04-606 - Seminar in Secondary Education	- 3
05-662 - Equal Educational Opportunity	- 3
04-619 - Teaching English: Secondary	-12
	36 sem. hrs.

II. Completion of the Secondary Education English Field of Knowledge Certification requirement. These requirements are prerequisites and must have been completed satisfactorily as a major in English as part of the baccalaureate degree.

*Other programs in Social Studies, Mathematics, Science, Psychology, have similar requirements. Copies of these are available upon request from the College of Education.

Semester Schedule

Summer Session I (4 weeks)		
*01-601-Developmental Psychology	3 s.h.	MTWTH 9:00-11:30
01-614-History American Education	3	MTWTH 12:00-2:30
	6 s.h.	
Fall Semester		
*01-602-Measurement and Evaluation	3 s.h.	
*04-645-Curriculum Development: Secondary School	3	
*04-615-Curriculum & Teaching English	3	Field-based
*06-605-Reading Education: Secondary	3	Field-based
*04-606-Seminar Secondary Education	3	Field-based
	15 s.h.	
Spring Semester		
04-619-Teaching English: Secondary	12 s.h.	
*05-662-Equal Educational Opportunity	3	
	15 s.h.	

*Pre-Practicum courses; total Pre-Practicum = 21 s.h.

Curriculum and Instruction Degree Program

The program in Curriculum and Instruction is designed for teachers in elementary and secondary schools who will provide instructional leadership in the role of supervisor or department chairman, and for those who will provide leadership in curriculum development in their role as a curriculum specialist.

The degree requirements include the following:

I. Behavorial and Humanistic Requirements

Area I. *01-621 Research Methods* or *01-622 Computer Literacy* is required of every student.

At least two other courses selected from Area II - *Humanistic Foundations,* or Area IV - *Sociological Foundations,* are required.

II. Specialization in Curriculum and Instruction

The following courses are required of all degree candidates:
04-641 Theory and Research in Curriculum
04-642 The Planning Process
04-643 Curriculum Design: K-12
04-646 Seminar in Curriculum and Instruction
04-649 Practicum in Curriculum and Instruction

III. Electives: Related Fields
Three or four courses must be selected from courses numbered 04, 05, or 06, with the advice and approval of the student's adviser.

IV. The Curriculum and Instruction degree program requires no less than 33 semester hours of course work.

Administration, Planning and Policy Degree Program

The master's degree program in Administration, Planning and Policy is designed to meet the needs of those planning careers as practitioners in a variety of middle-level administrative areas in public and private educational institutions as well as community organizations and various human service agencies. The program also serves as the initial sequence of study for those planning further graduate study in administration in preparation for careers as top-level administrators, planners, researchers or theorists.

As soon as a student is admitted to the degree program, a plan of study is individually designed by the student and adviser to meet particular career goals. Please note that students seeking certification in a variety of administrative or supervisory areas, particularly in public school settings, must be certain that all courses required for a particular certification are completed.

There is a common body of knowledge which those working in the area of administration should have in order to function effectively. Therefore, four basic courses are required of all degree students and should be taken early in the program. A course in research methods including basic knowledge of the function of computers is required. In addition, each student will participate in a practicum experience as part of the degree program.

Students have the option of pursuing one of two means of completing degree requirements:

A. Complete 36 academic hours including all required courses.

B. Complete 30 academic hours including all required courses and complete a project or paper of substantial depth which would illustrate the student's expertise.

A student undertaking a project or specialized paper must make a decision to do so early in the program so that he/she may work with the faculty mentor from initial stages to completion. Project and/or papers must be accepted by a faculty committee.

Students considering more advanced study in this area are encouraged to consider option B.

Please note: not all courses are offered every year; several are offered in alternate years only.

The programs listed below are in two strands: a program for School Administrators and a program for those engaged in Human Services Administration.

In each case, there are common course offerings.

I. Required Courses in Administration, Planning and Policy (4)

05-611 Introduction to Educational and Human Service Administration
05-642 The Planning Process (same as 04-642)
05-614 Analysis of Educational and Human Service Organizations
05-622 The Principalship

II. Humanistic and Behavioral Studies

In addition to one of the research methodology courses, two other courses are required in this area and may be selected from Area II, III or IV with the advice of the adviser.

III. Electives

05-612 Politics of Education and Human Services Policy Making
05-613 Labor Relations in Human Services
05-631 Citizen Participation in Education and Community Action Programs
05-641 The Human Service Administrator
05-643 Management of Human Services in School Settings
05-662 Educational Response to Cultural Diversity
05-663 Financial Aspects of Educational and Human Services Administration
05-664 Legal Policy in Educational and Human Services Administration

05-665 Principles of Supervision
05-671 Life Portraits of American School Systems and Human Service Organizations
05-691 Directed Study in Administration, Planning and Policy

IV. Practicum

05-629 Field Work: Elementary School Administration
05-639 Field Work: Secondary School Administration
05-649 Field Work: Human Services Administration

V. Professional Experience

Each candidate for the degree in Administration, Planning and Policy is required to have successfully completed no less than three years of full time employment in an educational institution or a human service agency prior to completion of degree requirements.

Reading and Language Degree Program (Ed.M.)

The degree program in Reading and Language is designed for those who wish to become specialists in reading and language either as special teachers or as consultants.

I. Core Requirements

Area I. 01-621 - *Research Methods* or 01-622 *Computer Literacy* is required of every student.

Area III. 01-631 - *Theories of Learning* is required of every candidate for the Ed.M. in Reading and Language.

One other course may be elected from Area II - *Humanistic Foundations* or Area IV - *Sociological Foundations* with the advice and approval of the student's adviser.

II. Specialization in Reading and Language

A. *Prerequisite Course Requirements*

Two prerequisites for admission to the course entitled "Clinical Assessment of Reading and Language" are satisfactory completion of prior courses both in the teaching of reading in the elementary school and in the teaching of reading in the secondary school. These prerequisites may be met by satisfactory completion of the graduate courses entitled "Developmental Reading: Elementary School" and "Developmental Reading: Secondary School." These courses do not accrue to the credit required for the degree.

B. *Required Courses*

06-641 Acquisition of Language
06-652 Clinical Assessment of Reading and Language Disabilities
06-653 Educational Treatment of Reading and Language Disabilities
06-654 Seminar in Reading and Language
05-665 Supervision of Instruction *or*
06-658 Organization and Supervision of Reading and Language Programs
06-659/201/202/203 Practicum: Reading and Language Disabilities

III. Electives

One or two courses must be selected from courses numbered 01, 04, or 06 with the advice and approval of the student's adviser.

IV. The Reading and Language degree program requires no less than 36 semester hours of course work including the 9 hours of Practicum.

Certificate of Advanced Graduate Study:
Reading and Language

The C.A.G.S. program is designed to give qualified professionals the opportunity for concentrated, in-depth study in a highly specialized area of Education. The program is designed for those reading educators already possessing certification as a Consulting Teacher of Reading and who wish to pursue advanced study within a special interest area. A second track or option is available for those with a strong career orientation toward the specialized area of Reading and Language and with an interest in obtaining certification as a Consulting Teacher of Reading. This option

would, of course, demand an extended period of study in order to fulfill both certification and C.A.G.S. requirements.

Course Sequence

I. *Core Requirements* - 9 s.h.
06-705 Issues in Reading and Language Instruction
06-720/721 Research Seminar in Reading and Language

II. *Reading and Language* - choose 12 semester hours
06-623 Issues in Children's Literature
06-632 Reading Institute
06-643 Workshop in Reading and Writing
06-650 Teaching Study Skills, Grades 4-14
06-651 Etiology of Reading
06-655 Reading, Listening, and Thinking
06-658 Organization and Supervision of Reading and Language Programs
06-702 Politics of Literacy Instruction
or any other course numbered 06.

III. *Allied Fields*

Three courses (9 s.h.) must be elected from courses numbered 04 - Curriculum and Instruction or 05 - Administration with the advice and approval of the student's adviser.

Course Descriptions

01-521 Tests and Measurement *Staff* **(3-0)3**
The course deals with test construction and analysis. Students are required to write, administer, and analyze the results of self-constructed tests. They also evaluate standardized tests. This introductory course is designed for students with no prior background in measurement.

01-522 Statistics *Staff* **(3-0)3**
Concentrates on both descriptive and inferential statistics. In descriptive statistics, the topics include central tendency, variability, correlation, and regression. Inferential statistics includes topics such as sampling and analysis of variance. In both areas, application is made to educational problems.

01-531 Dynamics of Group Process *Staff* **(3-0)3**
Participation and experience in a group setting serves as a practical base for an in-depth examination of theories underlying the dynamics of various types of groups.

01-601 Developmental Psychology *Catallozzi* **(3-0)3**
A study of the concepts and methodologies of the major theoretical systems (Genetic-Structural — Neo-Behavioristic) in Developmental Psychology; and the application of these concepts in a variety of educational settings.

01-611 Issues in Philosophy of Education *Wagner* **(3-0)3**
Topics of contemporary concern will be examined with a view to their philosophical bases. Where applicable, views of the great philosophers will be examined relative to these topics.

01-612 Contemporary Issues in Education *Lyons* **(3-0)3**
The course will concentrate on those philosophical disputes which have a direct relationship to the problems of education, namely, the school and social progress, the "open school", the validity of moral judgment, and education in the Third World.

01-613 Theories of Moral Education *Wagner* **(3-0)3**
Traditional and contemporary theories of moral education will be examined to determine differences in underlying assumptions and principles, whether moral education is a proper function of the school, especially in view of recent rulings on the separation of church and state, and assuming that it is, the implications of such theories for the curriculum and school environment. Special attention will be given to the work of Durkheim, Piaget, Kohlberg, Simon, and Skinner.

01-614 Issues in the History and Philosophy of American Education *Benson, Lyons* **(3-0)3**
Selected issues in contemporary American education will be examined in the light of their historical and philosophical origins. Students will examine the conflicts that have emerged and shaped American educational institutions. Current controversies in education will be addressed and students are expected to develop a point of view reflecting the history of the development of competing ideas.

01-618 Ethics of Education and Human Services *Wagner* **(3-0)3**
The dynamics of American culture and contemporary life pose serious ethical problems for education and other human service institutions; for each must identify its mission, establish priorities, allocate limited resources, serve clientele within the context of a society undergoing rapid social, economic, and technological change - a society where emerging values appear contrary to or at least less supportive of human service ideology.

In this course students will develop a better understanding of the dimensions and concerns of ethics, learn how to approach ethical questions more systematically, and analyze specific ethical problems in their respective professions.

01-619 Seminar: Justice, Equality, and Education *Wagner* **(3-0)3**
In the first part of this course, attention will focus on the concepts of justice and equality as fundamental principles governing the structure of society and its institutions. The utilitarian point of view will be examined, but special consideration will be given to the contract theory espoused by John Rawls in his book *A Theory of Justice*, and the analysis of human rights and equality presented by Benn and Peters in *Principles of Political Thought*. Since our ultimate concern will be the implications of these principles for education, for the structure and operation of schools, the second part of the study will be devoted to the more specific issue of educational opportunity and the problems of sexism, racism, and the ability grouping which it involves.

01-621 Research Methods *Staff* **(3-0)3**
The focus of this course is the construction of statistically testable hypotheses, the design of research studies appropriate to the hypotheses, and the application of statistical tests appropriate to the research designs. Evaluation of published research in accordance with established criteria will be required.

01-622 Computer Literacy *Staff* **(3-0)3**
This course offers an introduction to the computer in an educational setting. In addition to acquiring an understanding of how computers work, knowledge of hardware and software and familiarity with computer terminology, participants will explore current instructional uses and the power and potential of the computer in developing thinking and problem-solving skills.

01-631 Theories of Learning *Catallozzi* **(3-0)3**
A detailed analysis of the major contemporary learning theories, both behavioral and cognitive. Areas to be covered include: attention, motivation, S-R paradigms, cognitive progresses, Gestalt and field theories. Theorists studied include Bruner, Hebb, Kohlberg, Osgood, Piaget, Sears, Skinner, and Werner.

01-634 Social Psychology in Education *Catallozzi* **(3-0)3**
A conceptual and empirical study of social behavior within interpersonal, group, organizational, and community settings, both formal and informal. The major experimental studies undertaken in the areas of attitude formation, conformity, decision making, game theory, interpersonal attraction, altruism, aggression, etc., will be analyzed.

01-635 Individual Assessment Intelligence: Wechsler-Binet *Staff* **(3-0)3**
Prerequisite: Permission of Instructor
A laboratory course which provides intensive training in the techniques of administering, scoring and interpreting the Wechsler Intelligence Scale for Children (WISC), Wechsler Pre-school and Primary Scale of Intelligence (WPPSI) and the Stanford-Binet Intelligence Test. The theories of intelligence on which these tests are based will be considered.

01-637 Behavior Analysis and Management *Staff* **(3-0)3**
Considers current theory, research and practice of behavior modification with students. Primary emphasis is given to the analysis of behavior, the application of basic principles, and the techniques employed in the effective management of behavioral problems.

01-641 Issues in Sociology of Education *Phelan* **(3-0)3**
An intensive analysis of selected issues and problems in sociology of education. Through this course students develop cognitive skills in evaluating the findings and policy implications of research in the field. Information about the specific issues and problems to be discussed can be obtained from the Office of Education or from the instructor prior to registration.

01-642 The Organization of Schools and School Systems *Phelan* **(3-0)3**
The formal and informal social relationships of teachers, administrators, specialists, and pupils are examined for potential sources of role strain and role conflict. Problems of educational leadership are given particular

attention. Organizational opportunities for and constraints upon educational change are discussed.

01-643 The Professionalization of Educational Careers *Phelan* **(3-0)3**
This course focuses on the changing careers of teachers and administrators in our society. We will examine the development and expansion of colleague collaboration through educational associations, team-teaching, and informal social interaction. Professional responses to citizen pressures for teacher accountability and drastic reduction in school expenditures will be considered.

The role of the principal as a facilitator and promoter of teacher role demands and responsibilities will be analyzed.

01-644 Interpersonal Relations in Education and Human Services *Phelan* **(3-0)3**
This course examines the professional-client relationship from a social-psychological perspective. Through the use of role-playing, films, ongoing field experiences, and course readings, students will develop an understanding of the variety of role-demands and conflicts built into positions in Education and Human Services. Questions dealing with the authority of administrators and professionals will be addressed.

04-611 Curriculum Problems in English Education *Devine* **(3-0)3**
Based on the premise that curriculum development in English is made difficult by the uniqueness of the discipline itself, this course examines the nature of that subject matter in all its component parts in conjunction with contemporary curriculum theory. Emphasis is on delineating what it is about English as a subject matter that makes it problematic from a curriculum standpoint with constant attention as to how the problems can be solved.

04-612 Innovation and Change in the English Curriculum *Devine* **(3-0)3**
A review of English curriculum developments over the last quarter century with special emphasis on contemporary issues in education and how they affect the English curriculum and teaching. Areas of consideration include censorship, back to basics, minimal-competency testing, open classroom, grouping, values clarification, sophisticated media, the influence of the paperback, and the evaluation of teachers. The course will also consider future curriculum trends.

04-621 Problems and Innovations in the Mathematics-Science Curriculum *Demogenes* **(3-0)3**
Investigation of educational issues and problems in the mathematics or science area. Evaluative examination of instructional techniques and teaching materials in the curriculum revision projects of these disciplines.

04-622 Teaching Geometry *Demogenes* **(3-0)3**
This course will focus on the exploration of geometric concepts through investigation and a search for pattern. Opportunities will be provided for hands-on experiences with manipulatives which relate to the topics recommended in the mathematics curriculum of today's schools.

04-623 Teaching Science *Demogenes & Staff* **(3-0)3**
This course will be concerned with an examination of current teaching strategies and materials and analysis of the purposes and products of these techniques as employed in secondary schools.

04-625 Mathematics Laboratory *Demogenes* **(3-0)3**
Emphasis is on providing experiences and preparing materials in the development and implementation of the activity-centered classroom.

04-631 Curriculum Problems in Social Studies Education *Benson* **(3-0)3**
A brief historical review of social studies programs will provide the student with a perspective against which to examine current national programs (K-12). The student will develop a curriculum proposal for reform in the social studies.

04-632 Innovations in Social Studies Teaching Methodologies *Benson* **(3-0)3**
The students will study the development of the various methodologies used in the teaching of the social studies. Special emphasis will be placed on the inquiry method. Students will develop and demonstrate a teaching methodology for a specific project in the social studies.

04-641 Theory and Research in Curriculum *Benson, Biggy* **(3-0)3**
A study of the nature of the educational experience and the creation of curricula. The contemporary theorists' views of content, concept, experience, and curricula development will be examined and evaluated and matched with the research available in the curricula fields. This course will provide a theoretical base for continued specialization in the fields of curriculum and instruction.

04-642 The Planning Process (same as 05-642) *Meyer* **(3-0)3**
This is an introductory course on the methods and theories of planning. Setting goals and objectives, establishing priorites, undertaking a needs assessment for various kinds of short, and long range planning are some of the critical areas covered. Emphasis will center on planning for educational and non-profit organizations.

04-643 Curriculum Design: K-12 *Benson, Biggy & Staff* **(3-0)3**
This course will include a review of state mandates which, by law, shape the curriculum of the school, an examination of "new" curricula and the source of these, as well as the development of a rationale for curricula design and an evaluation of the personnel and techniques by which these curricula can be developed.

04-645 Program Evaluation *Meyer and Staff* **(3-0)3**
This course will develop a concept of program evaluation. The historical emergence of program evaluations will be considered, the evaluation tasks will be identified and the policy issues attendant to evaluation will be examined. The possible criteria and/or means for setting up evaluations and the number of commitments needed "in place" before program evaluation begins will also be addressed (Prerequisites: 01.621 and 04.642 or 05.642).

04-646 Seminar in Curriculum and Instruction *Staff* **(3-0)3**
Prerequisites: 04-641, 04-642, 04-643
Special emphasis will focus on contemporary research in the field and on research being done on national and international curriculum projects. The student will apply his/her research knowledge to individual investigations and analysis to give evidence of expertise in his/her field.

04-649 Practicum: Curriculum and Instruction *Staff* **(3-0)3**
Prerequisites: 04-641, 04-642, 04-643 and permission of the Department Chairperson
Supervised clinical experience. An opportunity to apply the skills and knowledge of curriculum development and evaluation of instruction which have been acquired in previous course work. The student will be expected to illustrate by performance in a school setting, his/her comprehension of the complexity and of the relationship between curriculum and instruction. This will be accomplished via special tasks designed by the student and faculty with the advice and approval of local administrators. The college faculty member, in consultation with the educational administrator with whom the student works, will evaluate the student's competency.

04-651 Seminar: Issues in Basic Skills Instruction *Biggy* **(3-0)3**
An investigation and evaluation of the call for a return to "basics." Consideration of the causes of renewed interest in "basics" and a review of current instruction in the basic skills. Students will be expected to develop a rationale and historical perspective from which to discuss intelligently "basic skills" instruction.

04-652 Seminar: Issues in Developing Career Awareness Programs *Benson, Biggy, Staff* **(3-0)3**
This seminar will be concerned with the rationale for career awareness programs; the issues of content and implementation of such programs and the impact of governmental agencies on the establishment of career awareness programs. All pertinent literature will be reviewed and the multifaceted concepts of career awareness will be examined toward the goal of developing a realistic definition and a proposed program of career awareness.

04-691 Directed Study in Curriculum and Instruction *Staff* **(3-0)3**
Prerequisite: Permission of the Department Chairperson
Through frequent consultation with the instructor, the student will investigate and define a problem for research in curriculum and instruction, and will present the findings in a significant paper. The directed study may not be substituted for a required course.

05-611 Introduction to Educational and Human Service Administration *Adamson, Staff* **(3-0)3**
This is a first course for students whose major is educational administration and supervision. The course acquaints the student with perspectives in educational administration and supervision over the past twenty-five years. This course considers current theories, concepts and practices in administration, the roles of administrative personnel, the process of administration, policy formulation, leadership behavior, organization and administration of public schools, the relationship of federal, state, and local agencies, and current issues related to administration and supervision. Participants will consider their relation to the role they contemplate and what it means to be an ethical and caring person in that role.

05-612 Politics of Education and Human Services *Meyer* **(3-0)3**
In order to understand the function of schools and human service agencies we must look beyond their perceived professional and philanthropic function and view them as political systems. In this course we will examine several major areas of concern in educational and human service sys-

tems. We will then focus on the political conditions and forces that not only shaped them but continue to shape these systems and their programs.

05-613 Labor Relations in Human Services *Lyons* **(3-0)3**
An introductory course on the theory of collective bargaining and its application. Emphasis will be placed on how decisions are made in such areas as wages, hours and conditions of work.

05-614 Analysis of Educational and Human Services Organizations *Meyer* **(3-0)3**
An examination of various models of organizational analysis used to explain events and relationships in complex social systems with emphasis on educational and human service institutions. Each student will develop a case study and analysis using organizational theory.

05-615 Ethical and Legal Frameworks for Administration of Educational and Human Service Organizations *Adamson* **(3-0)3**
Participants will consider traditional cultural and ethical sources which underlie "organized caring for others" and the reflection of these sources in judicial opinions, legislative arrangements and administrative frameworks which make caring for others possible.

Each participant will select a particular type of organization for study (educational, charitable, health, police, prison, etc.). Actual patterns of organizational acitivity will be examined in light of proclaimed institutional, administrative and legal goals. Variances will be related to the relevant descriptive literature.

Literature relating to the meaning of one's vocation as a teacher or human service contributor will be read, including reference to the loss of one's vocation, suffering and reshaping life goals for the future.

05-622 The Principalship *Adamson* **(3-0)3**
Course participants will consider not only "how to be a prinicipal" (plant management, budgeting, resource management, personnel practices, etc.) but what it means , ethically and personally, to be one. Modern and classical sources of wisdom on being a principal will be surveyed.

Case study problems drawn from actual legal controversies involving students, teachers, principals, parents and their communities will be used to simulate the climate and tensions which form part of the picture of giving leadership to schools.

05-629 Practicum: Elementary School Administration *Meyer, Staff* **(3-0)3**
Prerequisites: 04-642, 05-611, 05-614, 05-622 and permission of the Coordinator
Supervised clinical experience. Students acquire practical administrative experience in an elementary school under the direction of both the school administrator and a college faculty member.

05-631 Citizen Participation in Education and Community Action Programs *Meyer* **(3-0)3**
Citizen participation increases in times of expectation, it declines in times of despair. We have been through periods of neighborhood turmoil in the 60's and 70's, now in the 80's we appear to be in a period which is relatively quiet. What causes these periods of fluctuation in participation? How are citizen groups organized? Why are they organized? What gains

can they make by organizing? What are the most productive techniques for capitalizing on this interest? These and other questions will be addressed in this course.

05-639 Practicum: Secondary School Administration *Meyer, Staff* **(3-0)3**
Prerequisites: 04-642, 05-611, 05-614, 05-622 and permission of the Coordinator
Supervised clinical experience. Students acquire practical administrative experience in a secondary school under the supervision of both the school administrator and a college faculty.

05-641 The Human Service Administrator *Adamson* **(3-0)3**
Participants will read widely in the literature of administrative theory and supervision in order that they may develop keenness in analyzing problems and issues which arise in giving leadership to human service organizations, including schools, charitable organizations and foundations, health, police, prison, hunger, detention camp, and similar social missions. Each participant will choose a particular organization for case study.

05-642 The Planning Process (same as 04-642) *Meyer* **(3-0)3**

05-649 Practicum: Human Services Administration *Meyer, Staff* **(3-0)3**
Prerequisites: 04-642, 05-611, 05-614, 05-665 and permission of Coordinator
Supervised clinical experience. Students acquire practical administrative experience in a hospital, social service agency or similar institution under the direct supervision of both an agency administrator and a college faculty member.

05-662 Educational Response to Cultural Diversity *Meyer* **(3-0)3**
This course will focus on an investigation of the role played by schools in an expanding industrial society which is culturally pluralistic. The response of educational institutions to diverse ethnic groups in earlier times will be studied during the first part of the course. The effects of guidelines emerging from recent legislation on public education will be examined during the latter part of the semester.

05-663 Financial Aspects of Educational and Human Service Administration *Adamson* **(3-0)3**
Beginning with the passage of enabling legislation or the chartering of an institution, participants will examine how personal, moral and financial resources are marshalled and brought to bear in meeting the needs served by educational and other human service organizations. Perspectives in economic and organizational analysis, program definition, budgeting, management and plant management and performance evaluation will be studied.

Each participant will choose a particular kind of organization for study and for which to develop a model budget process.

05-664 Legal Policy in Educational and Human Services Administration *Adamson* **(3-0)3**
In order that they may act with confidence as administrators, students will learn how to read cases and how to research legal and administrative issues which define many of the activities of educational and human service organizations. Each student will develop materials which relate to

the current thinking of judges, legislatures, government agencies, and administrators as to how particular social problems and issues are to be resolved. Students will consider the extent to which their own leadership, or the leadership of others, may contribute to the resolution of issues and the improvement of applicable law.

05-665 Principles of Supervision *Biggy, Staff* **(3-0)3**
The focus of this course is on the interdisciplinary foundations of supervision. Attention will be given to the following areas: the function of theory, research on change, individual and group relationships in organizations, staff influence processes, talent utilization, and evaluation.

05-666 Personnel Administration and Educational Policy *Staff* **(3-0)3**
An introductory, overview course in personnel policies and practices in relationship to educational polices. Current personnel administration problems and educational issues will be discussed; emphasis will be placed on the value of behavioral sciences.

05-669 Issues in Staff Development *Meyer, Biggy & Staff* **(3-0)3**
This course will consider techniques for assessing staff needs, examine programs in operation designed to improve staff performance and will specifically address the design and strategy necessary to insure productive in-service education and staff development.

05-671 Life Portraits of American School Systems and Human Service Organizations *Adamson* **(3-0)3**
One way to learn administration is to become familiar with what has happened and what may be expected. The range of concerns about schooling and human services, including curriculum, personnel, budget, and relations with the larger society now is integrated and may be explored in contemporary law cases. Readings will include legal briefs, opinions, studies by consultants, and plans developed by school systems and human service organizations in response to judicial orders. Among the legal controversies to be studied, which compose descriptive journal narratives about school systems and human service organizations are those affecting Boston, Detroit, Cleveland, Los Angeles, Washington, D.C., Dallas and Benton Harbor.

05-691 Directed Study in Administration, Planning and Policy *Adamson, Meyer, Staff* **(3-0)3**
Prerequisite: Permission of the Faculty Chairperson
Through frequent consultation with the instructor, the student will investigate and define a problem for research and will present the findings in a significant paper. Faculty will assist students in defining topics. The directed study may not be substituted for a required course.

06-531 Developmental Reading: Elementary School *Staff* **(3-0)3**
The acquisition and development of reading skills by children in the elementary school will be studied. Special emphasis will be placed on the analysis of new curricula, and on methods and materials designed to facilitate the child's reading development.

06-532 Developmental Reading: Secondary School *Devine* **(3-0)3**
The continuum of reading skills from childhood through adulthood will be considered, with major emphasis on the acquisition and development of advanced reading skills by students in the secondary school.

06-621 Literature for Children *Kiernan* **(3-0)3**
The course will examine the importance of literature in the growth of the child, will consider ways of assisting children in developing a taste for the best literature, and will pursue strategies for organizing, projecting and evaluating a literature program.

06-622 Literature for Young Adults *Devine* **(3-0)3**
The major emphasis of the course will be discussion and analysis of the goals of a literature curriculum, and the exploration of various methods for achieving these goals.

06-623 Issues in Children's Literature *Kiernan* **(3-0)3**
Participants in this course will consider literature for children from several thematic approaches including materials which deal with war, sex, death and aging, divorce, minorities and the female. Readings, discussion and use of books in the literature program will be components of the course.

06-641 Acquisition of Language *McParland* **(3-0)3**
This course investigates the process by which language is acquired. The pertinent research, both historical and current will be critiqued, methods of investigating and analyzing language studies, and implications of language development in the acquisition of reading and language skills will be discussed.

06-645 Program Evaluation (same as 04-645) *Meyer and Staff* **(3-0)3**

06-650 Teaching Study Skills, Grades 4-14 *Devine* **(3-0)3**
An examination of research and successful teaching practices in skills and processes associated with the acquisition, assimilation, and expression of new information and ideas. The course is designed to help teachers improve student listening skills, textbook reading, vocabulary, library use, notetaking, comprehension, reporting, memory, test-making, motivation, and self-concept.

06-651 Etiology of Reading and Language Disabilities *McParland* **(3-0)3**
Considers the causes and theories of reading and language disabilities. Physical, neurological, genetic, cognitive, perceptual, and psychological factors are studied.

06-652 Clinical Assessment of Reading and Language Disabilities *McParland* **(3-0)3**
Prerequisites: 06-531 and 06-532 or their equivalents; a teaching certificate is required.
A major concern of the course is the selection and use of appropriate procedures for the purpose of making an adequate clinical and educational diagnosis. This includes the assessment of function and dysfunction in factors associated with language development: receptive, expressive, writing, reading; and the administration and interpretation of individual and group tests of perceptual, motor, and conceptual functioning in reading and language.

06-653 Educational Treatment of Reading and Language Disabilities *McParland* **(3-0)3**
Prerequisites: 06-652; a teaching certificate is required.
Students will be expected to develop realistic corrective programs based on the interpretation of academic, perceptual, motor, and language diag-

nostic assessment instruments. These programs will include selecting the proper strategies of instruction, the most productive materials, and establishing a framework of time and of evaluation for the programs.

06-654 Seminar in Reading and Language *Staff* **(3-0)3**
Prerequisite: Permission of Instructor
A final course with special focus on the national and international research being done on reading and language. An examination and analysis of that research, and a rigorous discussion about the pertinence and proposed implementation of research findings as to these fields of instruction will be undertaken. The various roles of the reading supervisor or director will be explored also. (Open to matriculated students only)

06-655 Reading, Listening, and Thinking *Devine* **(3-0)3**
An exploration of research and theory in language-thought relationships with emphasis on the improvement of higher mental processes through instruction in listening and reading.

06-658 Organization and Supervision of Reading and Language Programs *Niles* **(3-0)3**
Prerequisite: Permission of Instructor
Intended for practicing reading-language supervisors/consultants and for teachers who have a master's degree in reading-language education or its equivalent. Course will include organization and supervision of a reading-language program, evaluation of classroom instruction, selection of reading-language materials, coordination of the developmental program with remedial/corrective offerings, techniques of inservice education for various professional groups within a school system.

06-659 Practicum: Reading and Language Disabilities *Staff* **3-6 crs.**
Prerequisites: 06-652, 06-653, and permission of Reading and Language Coordinator
Supervised clinical experience. The student is expected to apply the skills and knowledge of diagnosis, perception and evaluation of reading and language disabilities which were gained in preceding courses. He/she is expected to illustrate by performance in a school or clinical setting his/her comprehension of the complexity of the task, and the interrelationship of diagnostic and corrective work via consultation with the educational administrators and specialists with whom the student works. (Open to students on matriculated status only)

06-691 Directed Study in Reading and Language *Staff* **(3-0)3**
Prerequisite: Permission of Reading and Language Coordinator
Through frequent consultation with the instructor, the student will investigate and define a problem for research in Reading and Language, and will present the findings in a significant paper. The directed study may not be substituted for a required course.

06-702 The Politics of Literacy Instruction *McParland, Niles* **(3-0)3**
Literacy in the United States and in the developed and developing nations of the world will be studied along with the socio-economic and political problems inherent within a literate population. Various techniques utilized in literacy instruction will be critiqued according to their success or failure from a political and social viewpoint.

06-705 Issues in Reading and Language Instruction *Devine, Niles* **(3-0)3**
Prerequisite: Permission of Instructor
Students will study such topics and issues as the subskills vs. holistic

theory of the reading process, the spinoffs from the competency testing basic skills trends, bilingualism as related to reading instruction, uses of electronic media in the schools, the newer types of print materials, relationship of learning disability instruction to remedial reading, and other emerging trends. Course is intended for professional personnel with prior study in excess of fifteen semester hours in the field of reading and language.

06-720,721 Research Seminar in Reading and Language *Staff* **(3-0)3**
Prerequisite: Permission of Reading and Language Coordinator

A conference course for students preparing C.A.G.S. qualifying papers in areas related to problems in reading and language. An examination and analysis of current research at the national and international levels will be conducted, and methods of implementation and dissemination of pertinent results will be discussed.


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COLLEGE OF ENGINEERING

Dean: Aldo M. Crugnola, Sc.D., Massachusetts Institute of Technology

DEPARTMENT OF CHEMICAL ENGINEERING

Department Chairperson: Norwood H. Keeney, Jr., *Professor;* B.S., Trinity College; M.S., University of Maine; Ph.D., University of Manchester, England; P.E. (New Hampshire).

Graduate Coordinator: Dominick A. Sama, *Associate Professor;* S.B., S.M., Sc.D., Massachusetts Institute of Technology.

Faculty

Huan-Yang Chang, *Associate Professor;* B.S., Southwest Associated University, China; M.S., University of Rhode Island; Ph.D., Iowa State University.

Ning Hsing Chen, *Professor;* B.S., National Chekiang University, China; B.Ch.E., Polytechnic Institute of New York; M.S., University of Missouri; D.Ch.E., Polytechnic Institute of New York.

Alfred A. Donatelli, *Assistant Professor;* B.S., M.S., Lowell Technological Institute; Ph.D., Lehigh University.

Charles J. Higgins, *Professor;* B.S., Lowell Technological Institute, P.E. (Mass.)

James A. Mann, *Associate Professor;* B.S., Rensselaer Polytechnic Institute.

Karl J. Sladek, *Associate Professor;* B.S., M.S., Sc.D., Massachusetts Institute of Technology.

John W. Walkinshaw, *Assistant Professor;* B.S., M.S., M.S., Lowell Technological Institute; Ph.D., Victoria University, Manchester, England.

Master of Science Degree Program

The graduate program in Chemical Engineering is designed to provide the opportunity for graduate students to study the fundamentals and applications of Chemical Engineering principles, and to carry out independent research.

Combined B.S./M.S. Program - Chemical Engineering

This department offers a combined B.S./M.S. program which results in an accelerated advanced degree. A description of the program may be found elsewhere in this catalogue and in the catalogue of undergraduate studies.

Admission Requirements

The Chemical Engineering Department will consider students for

enrollment in the program of graduate studies who have a Bachelor of Science degree in Chemical Engineering from a recognized college. Those with degrees in other areas must show proficiency equivalent to a Bachelor of Science degree in Chemical Engineering, including undergraduate prerequisites if necessary. In such cases, two to three years generally are required to complete the degree requirements.

Credit Requirements
A minimum of 30 semester hours of graduate course work and thesis, excluding seminar, will be required for all graduate students enrolled in the Department of Chemical Engineering. Each student shall enroll in at least two semesters of Seminar during the period of thesis research.

Plan of Study
Each student shall file a plan of study with the Department Chairman and Graduate Coordinator. This form will contain a listing of the courses which will make up his/her program. Any changes must have the approval of the Department Graduate Committee. Before a student may register for thesis, he/she must submit a written proposal of the thesis which has been accepted in writing by his/her major and minor thesis advisors.

Core Curriculum
The core curriculum in Chemical Engineering consists of at least 12 semester hours in the following courses:

10-503	Mass Transfer Operations I	(3-0)3
10-509	Mathematical Applications in Chemical Engineering	(3-0)3
10-514	Advanced Process Optimization	(3-0)3
10-517	Mass Transfer Operations II	(3-0)3
10-520	Advanced Chemical Engineering Thermodynamics	(3-0)3
10-528	Advanced Transport Phenomena	(3-0)3

Of the remaining 12 credits of course work, 6 to 9 credits should be in Chemical Engineering as described in the catalogue, and 3 to 6 hours may be in 500 series courses in Mathematics, Chemistry, Engineering, etc. Technical electives must have the approval of the departmental Graduate Committee. In unusual cases, graduate credit may be given for 400 level courses in the Department of Chemical Engineering as approved by the departmental Graduate Committee and/or the Graduate Coordinator.

Thesis

Before a student may register for thesis, he/she shall submit a written proposal of the thesis which has been accepted in writing by his/her major and minor thesis advisors. Each student will be required to undertake a 6 semester-hour thesis. All students will defend their thesis when completed according to Graduate School regulations. During the period the student is enrolled in graduate thesis, he/she will be required to submit a brief monthly report, showing progress of his/her thesis and approval by his/her advisor, to the staff of the Department.

Courses of Study

10-501 Paper Industry Process Analysis (3-0)3
Prerequisite: Permission of Instructor
Lectures dealing with the engineering processes of fiber separation from raw materials, fiber purification, mechanical processing of fiber and sheet formation. Chemical Engineering Theory is applied to the analysis of these operations.

10-503 Mass Transfer Operations I (3-0)3
Prerequisite: Permission of Instructor
Detailed coverage of the fundamentals of separation processes of absorption and extraction. Degrees of freedom, phase equilibrium diagrams, graphical techniques, molecular diffusion, interphase mass transfer, mass transfer and simultaneous chemical reaction. Design principles for multistage countercurrent contactors and continuous differential contact columns.

10-504 Process Calculations of Paper and Pulp Processes (3-0)3
Prerequisite: Permission of Instructor
Analysis of various chemical engineering processes encountered in the pulp and paper industry. The course provides a review of chemical engineering principles by application to the specific design and processes encountered in this industry.

10-506 Colloid Chemistry for Chemical Engineers (3-0)3
Prerequisite: Permission of Instructor
Colloid chemistry principles; zeta potential and its applications; specific problems involving surface chemistry and physics.

10-509 Mathematical Applications in Chemical Engineering (3-0)3
Prerequisite: Permission of Instructor
Application of ordinary and partial differential finite difference equations, integral transforms and generating functions in the solution of chemical engineering problems is emphasized with numerous real life examples.

10-511 Structure and Properties of Matter (3-0)3
Prerequisite: Permission of Instructor
Fundamental properties of matter as they relate to chemical engineering problems. Materials of construction. Rheological properties of polymeric materials and their application to chemical engineering.

10-514 Advanced Process Optimization (3-0)3
Prerequisite: Permission of Instructor
An advanced study of modern optimization techniques having applica-

tions in process economics, process analysis, process dynamics, process kinetics and process design; methods such as linear, non-linear, geometric, dynamic programmings, discrete and continuous maximum principles.

10-517 Mass Transfer Operations II **(3-0)3**
Prerequisite: Permission of Instructor
Fundamentals and modeling techniques for the separation process of distillation. Flash distillation, batch distillation, multicomponent distillation. Shortcut design method, Lewis-Matheson method, Thiele-Geddes method, Wang-Henke method, other methods. Optimization.

10-520 Advanced Thermodynamics **(3-0)3**
Prerequisite: Permission of Instructor
The central theme of this course is the use of the Second Law of Thermodynamics to reduce energy consumption in operations and processes in the chemical industry. Lost work analysis techniques are developed for the evaluation of thermodynamic processes. Areas of study include power cycles, refrigeration and distillation.

10-521 Introduction to Environmental Engineering **(3-0)3**
Prerequisite: Permission of Instructor
This is an introductory course to the problems of environmental pollution in all its aspects. Air and water pollution are given particular emphasis and special projects are assigned for student investigation. The course is concerned with the assessment and evaluation of the magnitude of the problem, but does not consider in depth the known or possible solutions to environmental pollution problems.

10-524 Advanced Chemical Process **(3-0)3**
Prerequisite: Permission of Instructor
Detailed study of several commercial processes from the standpoint of engineering principles and economics. Economics and interrelationships of the chemical industry. Analysis of specific real problems. Factors involved in determination of best design from several alternatives.

10-525 Advanced Heat Transfer **(3-0)3**
Prerequisite: Permission of Instructor
Review of principles of energy transport. Specific problems in convection and radiant heat transfer. Mathematical treatment of unsteady-state heat transfer.

10-528 Advanced Transport Phenomena **(3-0)3**
Prerequisite: Permission of Instructor
An advanced study of the mechanism of momentum, heat and mass transfer. The equations of continuity, motion and energy are used to examine steady and unsteady state processes. Transfer coefficients are defined at a microscopic and macroscopic level and the entire subject of unit operations is defined in terms of the equations of change. Considerable emphasis is placed upon solutions to problems.

10-530 Advanced Process Dynamics **(3-0)3**
Prerequisite: Permission of Instructor
An advanced treatment of the dynamics of linear and non-linear systems. Detailed study of the block diagram method and the LaPlace transform is used to write the closed and open loop responses to physical and chemical systems. Control system stability is studied and related by use of Bode

diagrams and Nyquist diagrams. System analysis and control by feed forward techniques are also considered together with experimental methods of obtaining dynamic response data.

10-532 Applications of Computers **(2-3)3**
Prerequisite: Permission of Instructor
Use of computers in the handling of engineering data. Development of techniques used in optimization problems and in plant design. Analysis of when and where to use computers in efficient solution of engineering problems.

10-601 Chemical Engineering Seminar **(1-0)1**

10-602 Chemical Engineering Seminar **(1-0)1**
Required of all graduate students.

10-651 Selected Topics in Chemical Engineering **(3-0)3**

10-652 Selected Topics in Chemical Engineering **(3-0)3**
Advanced topics in the various fields of Chemical Engineering. Content may vary from year to year to reflect contemporary applications of chemical engineering.

10-701 Graduate Research in Chemical Engineering **(0-9)3**

10-702 Graduate Research in Chemical Engineering **(0-9)3**
Every graduate student is required to perform research work done under the supervision of a senior chemical engineering staff member. This thesis or project must be approved by an examining committee appointed by the Department Chairman.

10-751 Advanced Projects in Chemical Engineering **(0-9)3**
Prerequisite: Permission of Department
Special projects laboratory undertaken by a student to expand his/her knowledge in specific fields not necessarily related to his/her thesis. Content of project, hour assigned and supervisor must be approved by the Department Chairman.

DEPARTMENT OF PAPER ENGINEERING (CHEMICAL ENGINEERING)

Faculty:

Charles J. Higgins, *Professor;* B.S., Lowell Technological Institute, P.E. (Mass.)

Norwood H. Keeney, Jr., *Professor and Chairman of Department;* B.S., Trinity College, Hartford; M.S., University of Maine; Ph.D., University of Manchester, England, P.E. (New Hampshire)

James A. Mann, *Associate Professor;* B.S., Rensselaer Polytechnic Institute.

John W. Walkinshaw, *Assistant Professor;* B.S., M.S., M.S., Lowell Technological Institute; Ph.D., Victoria University of Manchester, England.

Master of Science Degree Program

This program provides for advanced study and research training in paper engineering and allied subjects, with specific application to the paper industry.

Admission Requirements

The Paper Engineering Department will consider applicants in the following categories:

1. Graduates of the University of Lowell Chemical Engineering (Paper Option) program.
2. Graduates in Paper Engineering or Paper Technology from other universities.
3. General B.S. or M.S. graduates in engineering or chemistry with no previous training in paper engineering.

Credit Requirements

A minimum of 30 graduate credits excluding seminar is required to fulfill the requirements of a master's degree in Paper Engineering, delineated as follows:

A minimum of 12 credits in graduate Paper Engineering courses chosen from the courses outlined below in the 11- series.

A minimum of 12 credits in approved technical electives, i.e., technical subjects in the 500 series, or selected 400 courses in Chemical Engineering with approval of Graduate Coordinator and/or departmental Graduate Committee.

The following Research and Seminar courses:

11-701, 702 Research	(0-9)3, (0-9)3
10-601, 602 Engineering Seminar	(1-0)(1-0)2

Each student shall enroll in 10.601, 602, Engineering Seminar for two semesters during the period of thesis research.

Additional undergraduate subjects may be required of students who have deficiencies in their prior training.

Plan of Study
Each student shall file a plan of study with the Department Chairman and Graduate Coordinator. This form will contain a listing of the courses which will make up his/her program. Any changes must have the approval of the Department Graduate Committee.

Thesis
Before a student may register for thesis, he/she shall submit a written proposal of the thesis which has been accepted in writing by his/her major and minor thesis advisors. Each student will be required to undertake a 6 semester-hour thesis. All students will defend their theses when completed according to Graduate School regulations. During the period the student is enrolled in graduate thesis, he/she will be required to submit a brief monthly report, showing progress of his/her thesis and approval by his/her advisor to the staff of the Department.

Courses of Study

10-501 Paper Industry Process Analysis **(3-0)3**
Prerequisite: Permission of Instructor
Lectures dealing with the engineering processes of fiber separation from raw materials, fiber purification, mechanical processing of fiber and sheet formation. Chemical Engineering Theory is applied to the analysis of these operations.

10-504 Process Calculations of Paper and Pulp Processes **(3-0)3**
Prerequisite: Permission of Instructor
Analysis of various chemical engineering processes encountered in the pulp and paper industry. The course provides a review of chemical engineering principles by application to the specific design and processes encountered in this industry.

11-503-504 Advanced Converting Processes **(3-0) (3-0)6**
Prerequisite: Permission of Instructor
Specific converting processes. Analysis of coating processes; water and solvent based, extrusion and hot melts. Latest techniques used by the converting industry, involving mechanical and chemical operations. Engineering analysis of processes. Oral and written reports, plant visits, and laboratory assignments.

11-505 The Physics of Paper **(3-0)3**
Prerequisite: Permission of Instructor
Structures of fibers from a fundamental viewpoint and their effect on strength and other properties of sheets made of these fibers. Comparison of cellulosic fibers and synthetic fibers. Engineering properties of fibrous materials.

11-506 New Techniques in the Paper Industry **(3-0)3**
Prerequisite: Permission of Instructor
Lectures and discussions of new developments in engineering, design, and application of physical and chemical principles in the manufacture of

paper products. Economic comparisons of new processes. Oral and written reports, plant visits, and laboratory assignments.

11-507 Fundamentals of Reprography (3-0)3
Prerequisite: Permission of Instructor
An in-depth study of replicating and imaging systems from carbon paper to xerography, to halography, covering theory and principles of operation, design and development of hardware and supplies, typical specifications and a cursory economic evaluation of these systems. Because of the unique technical character of this new field, a review of copyright, patents and trade secrets is provided. The current state of the art is reviewed and the potential respresented by recent developments in the field is examined.

11-508 Advanced Paper Systems Analysis (3-0)3
Prerequisite: Permission of Instructor
Chemistry and engineering principles applied to non-fibrous components in paper making. Discussion of alum chemistry, fillers and other additives.

11-509 Economics of the Paper Industry (3-0)3
Prerequisite: Permission of Instructor
An evaluation of the paper industry from an economic viewpoint. Examination of costs and availability of different raw materials, additives and finishing materials. Analysis of competitive position of the paper industry and its products. Evaluation of foreign competition.

11-512 Advanced Fiber Processing (3-0)3
Prerequisite: Permission of Instructor
A study of fiber properties as related to fiber processing. Treatment of various theories of fiber processing. Discussion of mechanical treatments of fibers on the wet and dry properties of papers made from these fibers.

11-513 Non-cellulosics in the Paper Industry (3-0)3
Prerequisite: Permission of Instructor
An analysis of the role of non-cellulosics such as glass and polymeric materials in the field of paper technology. Characteristics imparted to paper structures and economics will be evaluated.

11-516 Analysis of Paper Formation Process (3-0)3
Prerequisite: Permission of Instructor
Discussion of the variables and factors involved in the formation of the paper web. Consideration given to fiber flocculation and orientation and to head-box design.

11-520 Environmental Problems in the Paper Industry (3-0)3
Prerequisite: Permission of Instructor
An in-depth study of the technical and economic aspects of the problems of the paper industry as they relate to environmental impact. Review of current technologies and assessment of future developments required to fulfill governmental requirements of EPA, OSHA and other agencies.

11-651 Selected Topics in Paper Engineering (3-0)3

11-652 Selected Topics in Paper Engineering (3-0)3
Prerequisite: Permission of Instructor
Advanced topics in the various fields of paper engineering. Contents may vary from year to year to reflect contemporary applications of paper engineering.

11-701 Graduate Research in Paper Engineering (0-9)3

11-702 Graduate Research in Paper Engineering (0-9)3
Prerequisite: Permission of Advisor

Every graduate student is required to write a thesis on original research work done under the supervision of a senior committee appointed by the Department Chairman.

DEPARTMENT OF CIVIL ENGINEERING

Department Chairperson: William B. Moeller, *Associate Professor;* B.S., Villanova University, M.S., Ph.D., University of Connecticut; P.E.

Graduate Coordinator: Nathan H. Gartner, *Associate Professor;* B.S., M.S., Sc.D., Technion-Israel Institute of Technology

Faculty:

Donald C. Leitch, *Associate Professor of Civil Engineering;* B.S., Lehigh University; M.S., University of Colorado; P.E.

Charles R. Ott, *Associate Professor;* B.S., M.S., Ph.D., University of Washington

Burton A. Segall, *Associate Professor;* B.C.E., Polytechnic Institute of Brooklyn; M.S.E., M.P.H., University of North Carolina; Ph.D., New York University; P.E.

John J. Sewell, *Associate Professor;* S.B., C.E., Massachusetts Institute of Technology; P.E.

Louis C. Tartaglione, *Associate Professor;* B.S., Manhattan College; M.S., University of Connecticut; P.E.

Master of Science Degree Program

Graduate study in Civil Engineering is an intensive, design and planning oriented program of instruction at an advanced technical level. (Instruction in the M.S.C.E. Program is planned for late afternoon and evening class meetings.) The program includes curricula in the areas of geotechnical engineering, structural engineering, transportation engineering, and water resources.

It is accepted that individual students have differing needs and career objectives. The program, therefore, permits each student to construct, in consultation with his advisor, a plan of study which is suitably balanced and in accord with his own goals.

A special combined BSCE/MSCE five year program is available to qualified undergraduate students at the University. Enrollment in this program will usually take place at the end of the junior year.

The objectives and philosophy of each of the curricula and the special requirements are outlined below.

The Five Year BSCE/MSCE Program

The purpose of this program is to offer qualified undergraduate students a coherent program of study whereby a Masters Degree in Civil Engineering may be realized at the end of 5 years of study.

The student benefits from the efficiency of a continuous, coordinated sequence of subjects which allows for reduced credit hour requirements.

General Requirements

A minimum grade point average of 3.0 is required for admission into the 5 year Civil Engineering graduate program; however, a student with an average between 2.75 to 3.0 may be admitted provisionally with departmental approval. The grades of the student's first 5 semesters will be used to determine the grade point average.

Applicants who satisfy the Graduate School and Civil Engineering Department admission requirements for the five year program will be assigned a Graduate Faculty member who will act as their program advisor. The first year M.S.C.E. degree requires the successful completion of a minimum of 30 credit hours. These 30 hours include at least 24 hours in class and seminar study of which at least 18 hours must be at the 500 level or higher. Also, at least 6 credit hours must be completed in preparation of a publishable thesis. Three credit hours for preparation of an engineering project report and an additional 3 hour 500 level course may be substituted for the thesis with the program advisor's approval. Courses at the 400 level are designed for seniors, but under certain circumstances may be taken by graduate students for graduate credit. The student must file a Special Petition form, obtainable from the Graduate School, at the time of registration for the 400 level courses.

Special Requirements

A student seeking a five year M.S.C.E. may undertake a general Civil Engineering program or may choose an area of specialized study. These areas include: Environmental Engineering, Geotechnical Engineering, Structural Engineering, Transportation Engineering and Water Resources. The student who specializes must take at least four electives in the area of specialization or from an associated area as approved by their program advisor.

Core Curriculum Requirements

All students are required to complete the following eight core cur-

riculum courses. It is recommended that they take at least 2 courses per term during their 4th and 5th years. The sequencing of the core curriculum courses will be determined by the student and his/her advisor considering the student's overall plan of study.

Fall Term	*Credits*
14-431 Foundations and Soils Engineering	3
14-452 Steel Design	3
14-460 Water Resources Engineering	3
16.348 Basic EE Concepts	3

Spring Term	*Credits*
14-470 Civil Engineering Economics	3
22-347 Elementary Thermo & Heat	3
14-461 Water Resources Designs*	3
16-214 Electric Machine Lab*	1

*Courses with Fall Term prerequisites

Typical Plan of Study

Fourth Year

Fall Semester		*Spring Semester*	
2 Core Curriculum Courses	6	2 Core Curriculum Courses	4 or 6
Area I or II Elective	3	Area I or II Elective	3
2 Civil Engineering Electives	6	2 Civil Engineering Electives	6
	15 hours		13 or 15 hours

Fifth Year

Fall Semester		*Spring Semester*	
2 Core Curriculum Courses	6	2 Core Curriculum Courses	4 or 6
2 Civil Engineering Electives	6	2 Civil Engineering Electives	6
Thesis	3	Thesis	3
	15 hours		13 or 15 hours

At least 6 of the required 8 Civil Engineering Electives must be at the 500 level or above. These courses may be taken in Civil Engineering or in an associated area approved by the student's advisor.

The thirty hours that are required for the master's degree are considered to be the following:

8 Civil Engineering Electives	24 hours
1 Thesis	6 hours
	30 hours

Under exceptional circumstances, a student wishing to terminate his/her plan of study before the completion of the 5th year

must at least successfully complete the 8 core curriculum course requirements, the 2 Area I or II Electives and the 2 Civil Engineering Electives which are part of this program, to obtain a BSCE.

Master of Science Degree Program

M.S.C.E. in Geotechnical Engineering

The master's degree program in geotechnical engineering will encompass soil mechanics theory and its application to practical engineering problems in the fields of foundation and soil engineering. The course work will emphasize the engineering properties of soil, how the properties are determined, and how they are used with soil mechanics theory in the solution of soil and foundation engineering problems. A B.S.C.E. degree or its equivalent is expected with at least one elementary course in soil mechanics and the usual civil engineering background in statics, strength of materials and hydraulics.

M.S.C.E. in Structural Engineering

The purpose of this area of study is to provide the student with advanced concepts and techniques which can be applied to the solution of complex structural engineering problems. A B.S. degree in engineering which includes senior level courses in the analysis of statically indeterminate structures and in the design of steel and concrete structures is required.

M.S.C.E. in Transportation Engineering

The program in Transportation Engineering offers a broad range of courses encompassing planning, design and operations of multimodal transportation facilities. It emphasizes a system-analytic approach to transportation and the interdisciplinary nature of the subject, drawing on techniques from management, economics, operations research and environmental studies. It is designed to provide the student with advanced technical knowledge for addressing transportation problems in a variety of situations. Specialization in a certain area can be achieved through thesis and project work.

M.S.C.E. in Water Resources

The program offers an opportunity to pursue a broad range of interests in the fields of environmental engineering and water resources. The course of study is designed to meet an individual student's interests and career goals. Programs consist of Civil Engineering courses in water and wastewater treatment, environ-

mental chemistry, hydrology, hydraulics, and courses from allied disciplines, in limnology, ecology, microbiology, environmental law, and organic and radiological chemistry.

General Requirements

Applicants who satisfy the Graduate School admission requirements will be assigned to a Graduate Faculty member who will act as their academic advisor. The M.S.C.E. degree requires the successful completion of a minimum of 30 credit hours. This includes at least 24 hours in class and seminar work at the appropriate level, and at least 6 hours in preparation of a publishable thesis, or 27 credit hours of class-seminar work and at least 3 hours in preparation of a project report.

During the first semester an advisory committee will be established for each degree candidate and each candidate will file a plan of study acceptable to the committee. Students accepted on a provisional basis will follow the same procedure. After having enrolled for 9 hours of instruction, the status of provisional students will be reviewed by the faculty who may then either admit them to matriculated status or refuse admission.

Those admitted to graduate study as non-degree students may reapply at a later date for matriculated status. However, no more than 9 credits of work completed while on non-degree student status will be used toward a degree. Faculty review of the petitioner's performance will follow the same criteria as used for provisional status petitioners. If accepted, the student will thereupon file an acceptable plan of study as required of all degree candidates.

M.S.C.E. in Geotechnical Engineering

Special Requirements

The student entering this program will be expected to have a B.S.C.E. degree or its equivalent, with at least one elementary course in soil mechanics and the usual civil engineering background in statics, strength of materials and hydraulics.

Core Courses

All students will be required to complete the following courses:

14-531 Advanced Soil Mechanics I
14-532 Advanced Soil Mechanics II
14-533 Advanced Foundation Engineering
14-534 Soil Dynamics
14-536 Soil Engineering

Elective Courses

The student is required to complete at least three courses in the following areas:

Engineering Geology
Advanced Structural Analysis
Advanced Strength of Materials
Structural Dynamics
Urban Transportation Planning
Groundwater Hydrology
Environmental Aspects in Planning
Engineering Systems Analysis
Stochastic Concepts

M.S.C.E. in Structural Engineering

Special Requirements

A student seeking an M.S.C.E. in Structural Engineering must have a B.S. degree in engineering which includes senior level courses in analysis of statically indeterminate structures and in the design of steel and concrete structures. Students deficient in these areas must take these courses as prerequisites before they can take advanced courses.

Core Courses

All graduate programs in structural engineering will be developed to meet the needs of the individual; however, each student should take or be able to show proficiency in the following courses:

14-504 Advanced Strength of Materials
14-550 Advanced Structural Analysis
14-551 Design of Steel Structures
or
14-552 Design of Reinforced Concrete Structures
14-557 Structural Dynamics
or
14-534 Soil Dynamics

Elective Courses

Additional courses taken from the Departments of Civil Engineering, Mechanical Engineering, Mathematics, Plastics Engineering, Economics, Management, etc., may be used to complete the student's program. At least one course in advanced engineering mathematics must be included in this group.

M.S.C.E. in Transportation Engineering

Special Requirements

Students desiring to enter the graduate program in Transportation Engineering should have an undergraduate engineering degree,

or be otherwise prepared in mathematics, physical science and engineering science. Students lacking an engineering background may also be admitted, but may be required to take selected courses in engineering fundamentals before taking advanced courses.

Core Courses

A Graduate plan of study will be determined to meet the professional needs of each student; however, at a minimum, each student is expected to have completed or show proficiency in the following courses:

14-441 Traffic Engineering
14-540 Urban Transportation Planning
14-581 Engineering Systems Analysis
14-583 Stochastic Concepts

Elective Courses

14-543 Transportation Systems Analysis
14-545 Public Transit Planning and Design
14-547 Airport Planning and Design
14-549 Analysis of Traffic Flows

Elective courses from other appropriate disciplines such as engineering, management, and pure and applied science may be taken to form a coherent program in Transportation Engineering.

M.S.C.E. in Water Resources

The Water Resources program offers the student advanced studies in environmental engineering, hydrology and hydraulics. Programs are individualized according to student interests and preparation and provide concentrated study in a selected area.

Special Requirements

Degree program students in environmental engineering and water resources must have a B.S. degree in engineering. Undergraduate course deficiencies in selected areas of study must be completed before taking advanced courses.

Core Courses

Two core courses are required in this area of specialization:

14-567 Environmental Chemistry I
14-583 Stochastic Concepts

Elective Courses

Individual programs consist of a complement of elective courses from within Civil Engineering, the College of Engineering, the College of Pure and Applied Sciences and other areas within the University.

14-504 Advanced Strength of Materials *Staff* **(3-0)3**
Stress and strain transformations; curved beam theory, unsymmetrical bending, shear center, torsion of non-circular sections; theories of failure; introduction to the theory of elasticity.

14-531 Advanced Soil Mechanics I *Staff* **(3-0)3**
and
14-532 Advanced Soil Mechanics II *Staff* **(3-0)3**
Nature of soil problems encountered in Civil Engineering; nature of soil, transmission of stresses between soil particles; behavior of dry soil; behavior of saturated soil for the conditions of stationary, steady state and transient flow conditions; application of principles of soil mechanics to the practical analysis and design of earth retaining structures, earth slopes and shallow foundations; laboratory testing of soils in relation to analysis and design.

14-533 Advanced Foundation Engineering *Staff* **(3-0)3**
Design and analysis of foundations required for various types of sub-soil conditions. The common type of shallow and deep foundations will be studied. Exploration and field tests and their application to design will be examined briefly.

14-534 Soil Dynamics *Staff* **(3-0)3**
Design of dynamically loaded foundations including the necessary elements of dynamics. Only an elementary dynamics course will be assumed as background. The principles to be developed will apply to dynamic loading due to machinery, earthquakes, or blasting.

14-535 Engineering Geology *Staff* **(3-0)3**
An introduction to the concepts and techniques of engineering geology. Topics will include the geology and morphology of glacial deposits; geological features and their engineering significance; use of borings and geophysical exploration techniques; geologic construction materials; ground-water, water supply, solid and liquid waste disposal; erosion and sedimentation associated with construction activities, reservoir silting and shoreline processes; and the geological factors considered in earthquake engineering. Case studies and term projects dealing with such activities as land-use planning, reservoir silting, water supply, and dam construction will be included. Certain geologic features and construction projects of New England will be visited during the semester.

14-536 Soil Engineering *Staff* **(3-0)3**
Soil as an engineering material and its use in earth structures. The types of earth structures to be treated will include road embankments, small earth dams, and compacted fills. The course will cover analysis and design of these structures and the pertinent field and laboratory soil tests necessary to obtain the soil properties. Soil grain and aggregate properties will be correlated with engineering characteristics. Natural slopes and unretained cut slopes will be analyzed for short term and long term stability. Trips to construction sites will be arranged where possible to view work in progress. The course will also deal with the selection and placement of field instrumentation necessary for construction control.

14-540 Urban Transportation Planning *Staff* **(3-0)3**
The urban transportation problem. Systems analysis approach to planning. Multimodal urban transportation planning process: goals and objectives; data collection, analysis, and model building; travel demand prediction, models: trip generation and distribution, modal choice, network assignment; evaluation of alternative plans.

14-543 Transportation Systems Analysis *Staff* **(3-0)3**
The course presents a framework for the analysis of a wide range of multimodal transportation problems. The basic paradigm: demand, supply and equilibrium. Models of transportation demand and their relation to the socioeconomic system. Modeling transportation technologies and performance functions. The network equilibration process. Prediction of impacts and searching for optimal strategies. Economic, social, environmental and political consequences of transportation decisions.

14-545 Public Transit Planning and Design *Staff* **(3-0)3**
The role of public transit in the overall urban transportation problem; developments in transit technology; transit system design and operating characteristics including accessibility, speed, capacity, headway and terminal layout and operation; analytical techniques used in transit design and planning; transit system simulation.

14-547 Airport Planning and Design *Staff* **(3-0)3**
Planning, locating and designing airport facilities; airport financing; air traffic control; aircraft characteristics; estimation of aeronautical demand; site selection and environmental effects; planning and design of terminals and heliports.

14-549 Analysis of Traffic Flows *Staff* **(3-0)3**
Models for the description of traffic flows on transportation facilities. Analysis of the levels of service and quality of service as influenced by physical design aspects and operational control measures. Both microscopic models (individual vehicle behavior) and macroscopic models (aggregate flows and their distribution in the network) will be addressed.

14-550 Advanced Structural Analysis *Staff* **(3-0)3**
Analysis of multi-story structures, frames and beam-columns with variable moment of inertia, continuous trusses and bents, arches and curved frames, structural stability, and beams on elastic foundations.

14-551 Design of Steel Structures *Staff* **(3-0)3**
Elastic and plastic design of structural steel systems, residual stresses; beam-columns; torsion; composite steel-concrete members; load and resistance factor design.

14-552 Design of Reinforced Concrete Structures *Staff* **(3-0)3**
Strength method; flexure analysis, deep beams, shear and torsion; beam-columns; deflections; two-way slabs; flat slabs; creep, shrinkage and temperature effects; prestressed concrete; limit analysis and design.

14-553 Timber Structures *Staff* **(3-0)3**
Design of timber members in tension, compression and bending; design of connections, laminated wood trusses and frames.

14-555 Structural Analysis by Matrix and Numerical Methods *Staff* **(3-0)3**
Basic structural analyses theories using Energy and Equilibrium techniques. Introductory studies of structures by use of finite differences,

finite elements and other iterative methods. Applications to truss, beam, and plate elements using computers. Special studies in elastic stability.

14-557 Structural Dynamics *Staff* **(3-0)3**
Analysis of structures subjected to dynamic loads; free, forced and damped vibrations with one or multi-degrees of freedom. Dynamic response of beams, framed structures, tall buildings and bridges, response to earthquake loadings.

14-559 Advanced Projects in Structural Engineering *Staff* **(3-0)3**
Studies of topics of special interest and need of the student in structural analysis and/or design.

14-561 Physical Chemical Treatment Processes *Staff* **(3-0)3**
Theories of physical chemical treatment processes and the laboratory (or pilot plant) techniques necessary to obtain design data for these processes. Treatment processes applicable to natural waters, domestic wastes, and industrial wastes will be studied. In addition to the development of design methods the relationship of these processes to overall environmental quality improvement will be stressed.

14-562 Ground Water Hydrology *Staff* **(3-0)3**
Description and analysis of the occurrence and movement of groundwaters. The response of groundwater to wells and solutions to well pumping and injection problems. Aquifer development, groundwater pollution and saltwater water incursion into aquifers.

14-563 Hydraulics of Open Channels *Staff* **(3-0)3**
Problems of varied or non-uniform flow in open channels will be investigated including methods for making surface and back-water profile determinations. Applications and typical cases will be of primary interest. Design capability should be enhanced for channel, canal, ditch, storm and sanitary sewer flow problems, and for hydraulics of reservoirs and treatment works under unsteady flow conditions.

14-564 Hydrology *Staff* **(3-0)3**
Basic hydrologic concepts, generation of input for design by processing of time series, correlations and frequency distribution.

14-565 Industrial Waste Treatment Processes *Staff* **(3-0)3**
An introduction to the unit operations most commonly encountered in industrial waste treatment. Specific industrial applications will be stressed after an understanding of each unit operation has been developed.

14-566 Biological Waste Treatment Processes *Staff* **(3-0)3**
Selection and design of aerobic and anaerobic biological waste treatment processes and process trains. Techniques for generating design data and prediction of process efficiency. Laboratory exercises will include bench scale and pilot plant studies of processes discussed in lecture.

14-567 Environmental Chemistry I *Staff* **(3-0)3**
The chemistry of natural and polluted waters and the applied chemistry of water and wastewater treatment. The course provides comprehensive coverage of dilute aqueous solution chemistry of acid-base reactions and complex formation.

An introduction to the chemistry underlying the processes that occur in natural bodies of water and at treatment facilities. The course emphasizes chemical equilibrium in water, and is intended as a foundation for further environmental studies.

14-568 Environmental Chemistry Applications *Staff* **(3-0)3**
The application of natural and polluted water chemistry. Lecture and laboratory projects develop analytical techniques and a knowledge of water treatment technology.

14-569 Advanced Projects in Water Resources *Staff* **(3-0)3**
Studies of topics of special interest and need of students in environmental engineering and water resources design.

14-581 Engineering Systems Analysis *Staff* **(3-0)3**
Introduction to methods of operations research, management science and economic analysis used in the design, planning and managing of engineering systems. Main topics covered are: the systems approach; optimization methods; network models; mathematical programming; organizational networks (CPM); decision analysis; economic criteria in systems planning; simulation methods.

14-583 Stochastic Concepts *Staff* **(3-0)3**
This course will present fundamental concepts involved in designing experiments and decision making in engineering to identify and analyze effects of uncertainties in engineering, define the role of limitations of stochastic concepts in engineering design and decision making. Emphasis is placed on practical applications of mathematical principles and tools of probabilty and statistics to problems in Civil Engineering.

14-651 Special Topics in Civil Engineering *Staff* **(TBA)**
Course content and credits to be arranged with instructor who agrees to direct the student.

Program in Environmental Studies (Civil Engineering)

Graduate Coordinator: Charles R. Ott, *Associate Professor;* Civil Engineering; B.S., M.S., Ph.D., University of Washington.

Faculty

Faculty of this department consists of faculty from the departments of Biology, Chemistry, Chemical Engineering, Civil Engineering and Radiological Science.

Master of Science Degree Program

This interdisciplinary program leads to a degree of Master of Science in Environmental Studies. It provides the students with (a) an overview of the entire area of environmental problems, including engineering, social, political and economic problems, and (b) a concentration in one of several fields of interest of his choice.

A graduate of this program will find application for his training with Federal agencies, local and state governments, consulting firms in the field of environmental control, or in industries which have environmental problems. The departments of Biological Sciences, Chemistry, Chemical Engineering, Civil Engineering, Radiological Sciences and Social Sciences all contribute to this program. A wide variety of courses is available to the students in the form of technical electives.

The program is open to qualified students in any of the engineering disciplines and in the biological or physical sciences. A Bachelor of Science degree in a scientific or engineering discipline is required. Other qualified students may be admitted provisionally with the approval of the Program Coordinator. Deficiencies in required course background may be made up while in the program.

Degree Requirements

Because of the diversity of background of students entering this program, it is frequently necessary for the student to make up deficiencies in his background by taking undergraduate courses. Normally these courses will include basic instruction in analytical procedure, both chemical and physical, an introduction to biology, and possibly an introduction to flow of fluids. Courses required for makeup of deficiencies will be determined by the Program Coordinator.

Requirements for graduation will include the following:

1. A minimum of 32 credits in Seminar, required core courses, electives, and thesis.
2. 18-601 Environmental Studies Seminar (1-0) (1-0)2
3. 18-701 Graduate Research in Environmental Studies (0-9) (0-9)6

Required Core Courses

18-510 Water Resources Management	(3-0)3
18-522 Solid Waste Management	(3-0)3
18-523 Air Resources Management	(3-0)3
18-527 Environmental Law	(3-0)3

Technical Electives

In general, technical electives may be chosen from any graduate level course in Chemistry, Biology, Civil Engineering, Chemical Engineering, Radiological Health or Energy Engineering. All technical electives must have the approval of the Program Coordinator.

Thesis

Each student will be required to undertake a 6 semester hour thesis. Students will choose a thesis adviser from a member of the staff approved by the Program Coordinator and two associate advisers, at least one of whom must be a member of the University of Lowell staff.

The student will be required to submit a proposal for his thesis for approval. Once the thesis is under way, brief monthly reports to the thesis advisers and to the Program Coordinator showing the progress of the thesis are required. Students are required to make a presentation at a Seminar Meeting when the thesis is completed and ready to be defended.

All students will defend their theses, when completed, in accordance with Graduate School regulations.

Advanced Research

Research areas being investigated presently include:

Septage Treatment
Heavy Metal Poliutant Removal
Heavy Metal Pollutant Uptake by Biological Means
Biological Predation in Mixed Cultures

Courses of Study

18-510 Water Resources Management *Staff* **(3-0)3**
A study of all actual and potential sources of portable and industrial waters is made with particular attention given to the origin, chemical composition and possible sources of contamination. Water purification methods are studied in detail including reclamation of saline waters, especially from a chemical engineering standpoint. Economic factors in purification in water distribution are also investigated.

18-522 Solid Waste Management **(3-0)3**
A detailed study is made of the various sources of waste and pollution from municipal, industrial, and other sources. An analysis of the various types of solid waste is made with an evaluation of methods of separation and possible recycling. Current technology of solid waste handling, including incineration, landfill and recycling are studied in detail. Economics of the various processes are discussed.

18-523 Air Resources Management **(3-0)3**
This course emphasizes the problems involved in air pollution and the technologies developed for its control. Methods of analysis and technology of removing gaseous contaminants and particulate solids from waste gas streams are emphasized. The chemical engineering aspects of these techniques constitute a major portion of the course. Economics of removal of contaminants is also emphasized.

18-527 Environmental Laws **(3-0)3**
The large body of law which has developed since the early 1960's is examined in considerable detail. Federal laws relating to the environment, particularly with the Environmental Protection Agency and the Occupational Safety and Health Acts, are studied in detail. Local laws and ordnances are discussed where pertinent. Legal procedures in handling complaints and court procedures are examined in detail.

18-552 Geochemistry *Eby* **(3-0)3**
Application of chemical principles to geologic problems. Topics include crystal chemistry, phase equilibria, stable isotopes and age dating, Eh and

pH of natural environments, abundance and distribution of elements in the earth, origin and evolution of igneous, metamorphic, and sedimentary rocks. The student will be required to write a research paper on a specific geochemical topic. Prerequisite: permission of instructor

18-553 Advanced Study in Earth Science *Staff* **(3-0)3**
The student, through regular and frequent consultation with an Earth Sciences faculty member, and the consent of his major department, will pursue a particular topic in the field of Earth Sciences which is directly related to his research area. Prerequisite: permission of instructor

18-555 Aerial Imagery Analysis *Ring* **(3-0)3**
A study of the methods of obtaining scientific records of the environment from aerial platforms, and the techniques of interpreting aerial photographic data for accurate detection of physical and cultural landscape features. Applications monitoring specific environmental conditions and environmental changes. Correlative readings and an applied term project are required for course completion. Corequisite: 18.557

18-557 Aerial Imagery Analysis Laboratory *Ring* **(0-2)1**

Department of Electrical Engineering

Department Chairperson: F. Ross Holmstrom, *Associate Professor;* B.S., University of Washington; M.S., Ph.D., Stanford University.

Graduate Coordinator: (Nights & Summers) Donn A. Clark, *Associate Professor;* B.S., Pennsylvania State University; M.S., Northeastern University.

Graduate Coordinator: (Days) Paul J. Murphy, *Associate Professor;* S.B., S.M., Massachusetts Institute of Technology; P.E.

Faculty

Francesco L. Bacchialoni, *Associate Professor;* Dott. Ing., University of Genova.

Roger H. Baumann, *Professor;* S.B., S.M., Massachusetts Institute of Technology; Sc.D., University of Paris.

Peter Burger, *Associate Professor;* B.S., Vanderbilt University; M.S., Ph.D., Stanford University.

George P. Cheney, *Assistant Professor;* B.S., M.S., Lowell Technological Institute.

Earle R. Laste, Jr., *Professor;* B.S., M.S., Northeastern University; Ph.D., Worcester Polytechnic Institute.

Martin A. Patt, *Assistant Professor;* B.S., Northeastern University; S.M., Massachusettts Institute of Technology.

James E. Powers, *Professor;* B.S., M.S., Lowell Technological Institute.

Frederick A. Rojak, *Associate Professor;* B.S., Pratt Institute; M.S., Lowell Technological Institute.

H. James Rome, *Assistant Professor;* B.S.E., (E.E.), M.S.E., (E.E.), University of Michigan; Ph.D., (E.E.), University of Pennsylvania.

David P. Wade, *Associate Professor;* B.S., Lowell Technological Institute; M.S., Northeastern University.

Master of Science Programs

Numbers in ( ) represent credit-hours — if no number is shown, course is three (3) credit-hours.

Thesis Option (30 credit-hours)				*Non-Thesis Option (33 credit-hours)*		
Electrical Engineering	Computer Engineering	Systems Engineering	Course Category	Electrical Engineering	Computer Engineering	Systems Engineering
16-509	16-500[2]	16-509	Required	16-509	16-500[2]	16-509
16-577	16-520	16-577		16-577	16-520	16-577
92-584	16-563	92-584		92-584	16-563	92-584
	16-574				16-574	
Five Courses (15)	Four Courses[2] (12)	Five Courses (15)	Electives[1]	Three Courses (9)	Two Courses[2] (6)	Three Courses (9)
12-701 (6)	16-701 (6)	28-701 (6)	Thesis or Seminar	16-601	16-601	16-601

Concentrations[3]

Control Systems	*Circuits & Systems*	*Software*	*Departmental*
16-513	16-528	16-522	Four courses
16-515	16-529	16-523	(12)
16-517	16-530	16-524	See M.S.S.T.
16-519	16-531	16-564	
Information & Communcations		*Firmware*	*Interdisciplinary*
16-543		16-561	Four Courses
16-545		16-562	(12)
16-547		16-564	See M.S.S.T.
16-548		16-575	
Computer Hardware	*Computer Software*	*Hardware*[4]	
16-525	16-522	16-525	
16-561	16-524	16-561	
16-574	16-563	16-562	
12-575	16-564	16-575	

[1]See OPTIONS under Thesis for further specification of electives.
[2]M.S.C.P.'s with B.S.E.E. background will not receive credit for 16-500 but must sbustitute a (3) credit-hour graduate course.
[3]Students electing the Non-Thesis Option must take one of the concentrations indicated under the desired degree.
[4]Holders of B.S.E.E. degrees only.

Master of Science Degree Programs

The Department of Electrical Engineering offers degrees at the master's level in the following programs:

1. Master of Science in Computer Engineering (M.S.C.P.)
2. Master of Science in Electrical Engineering (M.S.E.E.)
3. Master of Science in Systems Engineering (M.S.S.T.)
4. Combined Five Year B.S./M.S. Program in all the above programs.

Entrance Requirements

To be eligible for admission to the Electrical Engineering graduate program an applicant must have received a bachelor's degree or equivalent with an acceptable quality of undergraduate work from a recognized college or university. The G.R.E. Aptitude examinations are required. Both the quality and quantity of previous training are considered. General entrance requirements and procedures will be found under "Admissions" in this catalogue.

Options

The requirements for any of the three Master of Science degrees offered by the Department may be satisfied by either of the following options:

Thesis Option

The completion of 30 credit hours of approved study including a thesis of 6 credit hours, certain required courses, and the balance in electives. Normally these electives will be graduate electrical engineering subjects but may, on approval of the student's academic adviser, be chosen from other engineering or scientific disciplines. These electives may also include all or part of one of the specific concentrations described under the non-thesis option.

Non-Thesis Option

The completion of 33 credit hours of approved study including a 3-credit-hour seminar course (16-601) and the successful completion of four courses of 3 credit hours each in one concentrated area elected by the student, certain required courses, and the balance in electives. The 16-601 Seminar in Electrical Engineering will require the student to select a topic with the advice and consent of his instructor. In addition to presenting a short paper, the student will be required to make an oral presentation of his investigation and a defense of his work before his class and other faculty members who may choose to attend. Each student will be judged on his/her clarity of exposition, knowledge of the subject, ability to

answer questions clearly and effectively, as well as his/her own participation in the discussion of other papers. Only fully matriculated students are allowed to register for the 16-601 Seminar.

Thesis
No student is allowed to register for a thesis until he/she has achieved the status of matriculated student and until such time as he/she has obtained the approval of a *written proposal* which outlines clearly the extent and nature of his/her proposed work. A thesis must be based on the results of analytical or experimental work of a creative nature and must, unless otherwise authorized, be performed under the supervision of a faculty member who may or may not be the student's academic adviser. The student will be required to give an oral defense of his work before his/her committee, consisting of a major thesis adviser and two other minor advisers. Other faculty members are invited to attend the oral presentation. Instructions for preparing proposals, as well as detailed specifications for the final written report, are available from the Graduate Coordinator of the Department. A thesis normally carries six hours of credit but may in unusual cases be extended upon approval of a written petition to the Graduate Curriculum Committee.

Non-degree student credit transfer. A student may transfer a maximum of 12 credits earned as a non-degree student toward the master's degree in any program in Electrical Engineering.

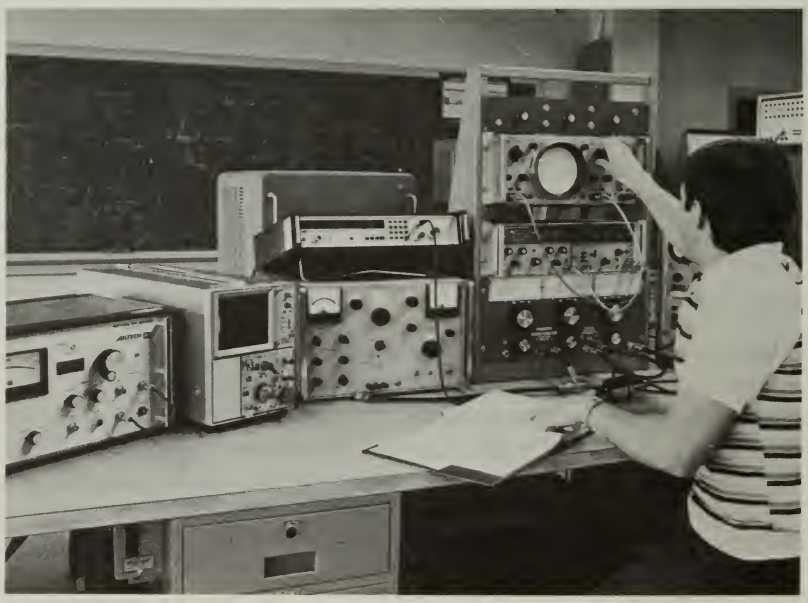
Credit for Undergraduate of 400 Level Courses
Although the Master's degree candidate normally is expected to take graduate level courses for his degree requirements, certain 400 level Electrical Engineering courses and certain Applied Physics and Mathematics courses are acceptable for graduate credit when approved by the student's academic adviser. However, not more than 6 credit hours of these courses may be used to satisfy the degree requirements. (In the M.S.C.P. program, 16-411 and 16-417 are considered undergraduate prerequisites and will not receive graduate credit.)

Evening Courses (Continuing-Education)
Admission requirements for the part-time evening program leading to the degree of Master of Science are the same as for the full-time program, but students may progress according to their abilities and the time available. A number of courses are offered through the Division of Continuing Education, and these courses are interchangeable with the corresponding day school courses.

Dual Enrollment in Day and Evening Courses:
Although the department does not lay down a firm residency policy for the Master's degree, it is expected that the student will become acquainted with professionals in the field of engineering. This exposure can be obtained by either full-time day school enrollment for a minimum of 21 credit-hours but not less than 8 credit-hours per semester (i.e., 8-8-5 minimum) or by full-time employment in a local electronic or related industry.

With respect to the minimum course load required for teaching and research assistantship appointments, only the day load will be counted. Special written permission must be received from the student's advisor and the Graduate Curriculum Committee of the department before a day student will be allowed dual (concurrent day and Continuing Education) registration. Such permission will be allowed only in extenuating circumstances. There is no impediment for Continuing Education students taking day courses.

Academic Adviser
Each graduate student admitted into Electrical Engineering Department will be assigned an academic adviser who will assist him/her in the selection of courses and who will develop with the student a program which will meet his/her needs and the requirements for the desired degree.



Selection of Major Adviser for Thesis

The following table delineates the current areas of interest of the faculty of the Electrical Engineering Department and is intended to assist the student in contacting and choosing a compatible major adviser for his/her thesis. The areas are defined below:

Area I	Control Systems
Area II	Communications and Information Theory
Area III	Circuits and Systems
Area IV	Computer Software
Area V	Computer Hardware, Electronics and Systems
Area VI	Microwave and Field Theory
Area VII	Biomedical Engineering

Staff Member	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*
R. H. Baumann	X	X	X				
F. L. Bacchialoni	X		X				
R. D. Brunelle	X		X				X
P. Burger				X	X		
G. P. Cheney				X	X		
D. A. Clark	X	X	X				
F. R. Holmstrom		X	X		X		
E. R. Laste	X	X		X	X		
P. J. Murphy	X	X	X	X	X		
M. A. Patt				X			
J. E. Powers				X	X		
F. A. Rojak		X		X	X	X	
H. J. Rome	X	X					
E. P. Sayre				X	X		
D. P. Wade	X						
A. D. Wunsch						X	

Master of Science Electrical Engineering (M.S.E.E.)

The Master of Science program in Electrical Engineering offers professional training for the student desiring a broader or deeper understanding of such areas as circuit theory, control systems, information and communication theory, electronic circuits, solid state electronics, computer hardware and software.

Each student entering this program is expected to have received a Bachelor of Science in Electrical Engineering with an acceptable quality of undergraduate work from a recognized college or university. An applicant with a Bachelor's degree in other engineering or related fields normally will be accepted as a provisional student until such time as the student has completed those

undergraduate courses specified by the Graduate Committee of the Department.

Required Courses

Candidates for the degree of M.S.E.E. will be required to complete the following three courses, irrespective of the thesis or non-thesis option, as part of the overall requirements for the degree.

16-509	Linear Systems Analysis	(3-0)3
16-577	State Variable Analysis of Systems	(3-0)3
92-584	Analysis of Random Processes	(3-0)3

(See Mathematics Department course descriptions)

In addition to the above required courses, students electing the thesis option will be required to complete 15 credit hours of elective course work and a 6-credit-hour thesis (16-701) making a total of 30 credit hours.

Students electing the non-thesis option will be required to complete the following program of study for a total of 33 credit hours.

1. Nine (9) credit hours of required courses described above
2. Twelve (12) credit hours of courses from one of the concentrations listed below (M.S.E.E.)
3. Nine (9) credit hours of elective course work
4. Three (3) credit hours of Seminar (16-601)

The student may satisfy the 12-credit-hour concentration requirement by selecting any one of the following groups of four subjects. The courses must be taken as a block — these groups cannot be subdivided or intermixed in meeting the concentration requirement.

Control Systems	*Computer Hardware*	*Information & Communications*	*Computer Software*	*Circuits & Systems*
16-513	16-525	16-543	16-522	16-528
16-515	16-561	16-545	16-524	16-529
16-517	16-574	16-547	16-563	16-530
16-519	16-575	16-548	16-564	16-531

Master of Science in Computer Engineering (M.S.C.P.)

The Master of Science program in Computer Engineering offers professional training for the student desiring a broader or deeper understanding of such areas as digital, analog, and hybrid devices and techniques. Although the required courses in this program attempt to provide the essential background in electrical engineer-

ing, computer mathematics and programming, and digital systems design, the main thrust of this program is in computer software on the one hand and in the area "between" hardware and software on the other. For brevity we refer to this latter area as *firmware*. It is felt that the detailed study of computer hardware requires a Bachelor of Science in Electrical Engineering degree or equivalent, hence the hardware concentration is open to holders of a BSEE degree only.

Each student entering this program is expected to have received a Bachelor of Science degree in engineering, mathematics, or the physical sciences from a recognized college or university with an acceptable quality of undergraduate work. In certain cases promising students with B.A. degrees and the necessary mathematical background will be admitted provisionally, pending the make-up of any academic deficiencies. The following University of Lowell undergraduate courses or their equivalent are considered prerequsites for the M.S.C.P. program and must be taken by those who are deficient in them:

16-227	Programming and Applications of Digital Computers I	(2-0)2
16-228	Programming and Applications of Digital Computers II	(2-0)2
16-411	Logic Design of Digital Systems I	(3-0)3
16-417	Absolute and Symbolic Programming	(3-0)3

(See undergraduate catalogue for course descriptions)

Applicants who have not taken the above four courses or their equivalent but who otherwise show promise of satisfactorily completing the M.S.C.P. program will be admitted as provisional students until such time as they have removed these deficiencies.

Candidates for the degree of M.S.C.P. will be required to complete the following four courses, irrespective of the thesis or non-thesis option, as part of the overall requirements for the degree:

16-500*	Principles of Electrical Engineering	(3-0)3
16-520	Numerical Computing	(3-0)3
16-563	System Programming	(3-0)3
16-574	Introductory Digital System Design	(3-0)3

*M.S.C.P. candidates with a B.S.E.E. background will not receive graduate credit for 16-500 but must substitute a 3-credit-hour graduate elective in its place.

In addition to the required courses above, students electing the thesis option will be required to complete 12 credit hours of elective course work and a 6-credit-hours thesis (12-701).

Students electing the non-thesis option will be required to complete the following program of study for a total of 33 credit hours:

1. Twelve (12) credit hours of required courses described above (See 16-500 exception for B.S.E.E. backgrounds)
2. Twelve (12) credit hours of courses from one of the concentrations listed below (M.S.C.P.)
3. Six (6) credit hours of elective course work
4. Three (3) credit hours of Seminar (16-601)

The elective course work must meet the same conditions as those specified under the thesis option above. (See options under non-thesis concerning 16-601.)

The student may satisfy the 12-credit-hour concentration requirement by selecting any one of the following three groups of four subjects. The courses must be taken as a block — these groups cannot be subdivided or intermixed in meeting the concentration requirement.

Software	*Firmware*	†*Hardware*
16-522	16-561	16-525
16-523	16-562	16-561
16-524	16-564	16-562
16-564	16-575	16-575

†For holders of the BSEE degree only.

Master of Science in Systems Engineering Program (M.S.S.T.)

The Master of Science program in Systems Engineering offers professional training for students desiring a broader or deeper understanding of relatively complex electrical systems, such as controls, communications, computers, and combinations of these systems. Because of the general nature of systems work, the student is not usually expected to have knowledge of the detailed operations of each component but rather an understanding of the salient characteristics and the interactions between components of the system. Hence, it is possible for a student to obtain an interdisciplinary degree by studying in more than one department. In such cases an interdisciplinary committee will be formed, and the student's specific program will be formulated.

Each student entering the Master of Science program in Systems Engineering is expected to have received a Bachelor of Science degree in engineering, mathematics, or the physical sciences from a recognized college or university with an acceptable quality

of undergraduate work. Students who are weak in basic principles of electrical engineering are encouraged to enroll in 16-500.

Candidates for the M.S.S.T. degree will be required to complete the following three courses, irrespective of the thesis or non-thesis option, as part of the overall requirements for the degree.

16-509	Linear Systems Analysis	(3-0)3
16-577	State Variable Analysis of Systems	(3-0)3
92-584	Analysis of Random Processes	(3-0)3

(See Mathematics Department course descriptions)

In addition to the above required courses, students electing the *thesis option* will be required to complete 15 credit hours of elective course work and a 6 credit-hour thesis (28-701), making a total of 30 credit hours. (See options under Thesis regarding electives.) Students working for interdisciplinary degrees must have their entire program approved by their interdepartmental committee, as well as the Graduate Curriculum Committee of the Electrical Engineering Department, with prior approval required.

Students electing the *non-thesis option* will be required to complete the following program of study for a total of 33 credit hours:

1. Nine (9) credit hours of required courses described above
2. Twelve (12) credit hours of courses which constitute a concentration and which have the prior approval of the student's academic adviser and the Graduate Curriculum Committee.
3. Nine (9) credit hours of elective course work.
4. Three (3) credit hours of Seminar (16.601).

The elective course work must meet the same conditions as those specified under the thesis option above. (See options under non-thesis concerning 16.601).

M.S.S.T. concentrations: Because of the wide range of topical coverage in Systems Engineering and because of the interdisciplinary option, no specific concentrations are delineated. However, the student may satisfy the 12-credit-hour concentration requirement by obtaining the advice and consent of the adviser in setting up a meaningful concentration to suit the needs of the student.

Combined Five Year B.S./M.S. Program

Regularly enrolled undergraduate students who have achieved above average academic standing through their sophomore year are encouraged to consider the combined B.S./M.S. program which is expected to lead to both degrees by the end of the student's fifth year at the University. In order for this program to be meaningful the student must make his commitment to the program no later than the beginning of his junior year.

The main benefit of this program is that both the student and the adviser identify the student's academic objectives early in his/her work at the University so that a very efficient and well structured program can be devised which will minimize the chances of losing courses when offered due to a lack of prerequisites. Because of scheduling and prerequisite problems very few if any of our regular graduate students complete the Master's degree program in one year. The five year program circumvents many of these difficulties.

A suggested program of courses and their sequencing is shown below. The following assumptions are made with respect to students admitted to this program.

1. The student must be committed to the program by the beginning of the Fall term of the junior year.
2. The students withdrawal from the five year program after the completion of the fourth year, will not effect eligibility for the B.S. degree, provided all work has been satisfactorily completed up to that point in the five year program.
3. Although the option of registering for summer school at the University exists, it will not be required by the program. In fact, *with prior approval,* students will be allowed to take up to 6 credit-hours of course work at other accredited institutions and receive transfer credit for all graduate courses carrying a grade of B or better. The usual transfer credit petition must be filed and approved after grades have been received.
4. A student wishing to pursue the non-thesis option should take one graduate course during the summer between the fourth and fifth year and substitute the Seminar (16.601) and one more graduate level course in lieu of the 6 credit-hours of Thesis in the fifth year.

The following program of study is suggested for students admitted to the combined B.S./M.S. program in Electrical Engineering.

Junior Year

Fall Semester

16-311	Electronics Laboratory I	2
16-362	Signals and System Anal.	3
16-365	Electronics I	3
92-315	Complex Variables for Engrs.	3
HS #1A	Humanistic-Social Elective	3
*16-411	Logical Design of Digital Systems I	3
		17

Spring Semester

16-312	Electronics Lab II	2
16-355	Intro. Electromechanics	3
16-366	Electronics II	3
13-360	Electromagnetic Theory I	3
22-212	Intro. Mechanics	4
*16-417	Absolute & Symbolic Programming	3
		18

*MSEE and MSST may use other 400 level courses if desired or take standard program.

Senior Year

Fall Semester

HS #2	Humanistic-Social Elective	3
16-461	Electromagnetic Theory II	3
22-347	Elements of Thermodynamics and Heat Transfer	3
G.C. #1	Graduate Course #1	3
G.C. #2	Graduate Course #2	3
		15

Spring Semester

HS #3	Humanistic-Social Elective	3
HS #4	Humanistic-Social Elective	3
16-413	Linear Feedback Systems	3
G.C. #3	Graduate Course #3	3
G.C. #4	Graduate Course #4	3
		15

Summer Preceding Graduate Year

The student will be expected to develop and write a PROPOSAL for his/her thesis and have it ready for the start of the Fall term. (No formal registration involved.)

Graduate Year

Fall Semester

G.C. #5	Graduate Course #5	3
G.C. #6	Graduate Course #6	3
XX 701	Thesis	3
T.Elec.	Technical Elective #2	3
Und.El.	Undesignated Elective #1	3
		15

Spring Semester

G.C. #7	Graduate Course #7	3
G.C. #8	Graduate Course #8	3
XX 701	Thesis	3
T.Elec.	Technical Elective #3	3
Und.El.	Undesignated Elective #2	3
		15

It should be noted that the selection of 16-411 and 16-417 in the junior year is primarily for students working toward a Master of Science in Computer Engineering (M.S.C.P.) which is considered to be the "worst case" for purposes of scheduling and prerequisite satisfaction. In the case of MSEE or MSST the student may elect to take these courses or take a standard junior year, depending upon the phasing of our graduate course offerings.

16-500 Principles of Electrical Engineering *Staff* **(3-0)3**
Prerequisite: B.S. in Engineering or Science
Fundamental definitions and circuit laws with applications. Important network theorems such as superposition and Thevenin's theorem. First order transients and forced responses. Diode, transistor, and FET large-signal models. Pulse and digital circuits including transistor and FET switches, waveshaping schemes, multivibrators and logic gates. Switching-speed, propagation times, fan-in and fan-out characteristics of DTL and TTL logic families.

Although this course is primarily intended for students whose undergraduate major was in an engineering or scientific discipline other than electrical engineering, it is also recommended for students who have received their Bachelor of Science in Electrical Engineering degree more than five years ago and who feel the need for a review of electrical principles. In any case, graduate credit will be given only to M.S.C.P. and M.S.S.T. degree candidates not holding a B.S.E.E., while those with the B.S.E.E. degree must substitute a three (3) credit-hour elective to satisfy the requirements for the M.S.C.P. degree.

16-503 Solid-State Physical Electronics I *Staff* **(3-0)3**
Prerequisite: 16-360
Introduction to the behavior of solid-state electronic devices from the viewpoint of modern physics; review of classical mechanics and Maxwell's equations. The Bohr atom, wave-particle duality, wave packets, Schroedinger's equation, band theory of solids, electrons and holes. Mechanical and acoustical properties of solids, semiconductor behavior.

16-504 Solid-State Physical Electronics II *Staff* **(3-0)3**
Prerequisite: 16-503
Continuation of EE 503. Semiconductor devices: Schottky diodes, p-n junction devices, junction transistors, field-effect transistors, photodiodes, varactors. Electro-optic devices, thermo-electric devices, electroluminescent diodes and laser diodes. Magnetism and magnetic devices.

16-505 Microwave Electronics *Staff* **(3-0)3**
Prerequisite: 16-461
Design oriented course dealing with Solid State Active Microwave Devices. Amplifiers, Oscillators, Switches, Modulators, Mixers, Limiters. Realization of Microwave Systems through MIC (Microwave Integrated Circuit) Techniques. Computer Analysis Aids for Microwave Designs.

16-507 Electromagnetics I *Staff* **(3-0)3**
Prerequisite: 16-461
Maxwell's Equations, Poynting's Theorem, Boundary Value Problems in Electrostatics and Electrodynamics, Green's Functions, Retarded Potentials, Reflection and Refraction of Plane Waves, skin effect, Wave Guides.

16-508 Electromagnetics II *Staff* **(0-9)3**
Prerequisite: 16-461
Wave Propagation in Plasma and Ferrites, Space Charge Waves, Microwave Circuits, Elementary Antenna Theory, the Dipole, Loop, and Simple Arrays, Huygen's Principle and Radiation from Apertures.

16-509 Linear Systems Analysis *Staff* **(3-0)3**
Prerequisite: 16-362
Classical solution of linear systems described by differential equations.

Duals, analogs, and electromechanical systems. System function, step and impulse response, and initial conditions. Time-domain convolution. Fourier analysis, series, and integral: impulse method for obtaining transforms. Laplace transforms: evaluation and properties. Complex variable theory: complex differentiation and Cauchy-Riemann equations. Complex integration: Cauchy's theorem and Cauchy's integral formulas. Taylor and Laurent series and the residue theorem inverse LaPlace transforms. Introduction to Z-transforms.

16-513 Linear Control Theory-Analysis *Staff* **(3-0)3**
Prerequisite: 16-362
Transient performance of linear feedback control systems for deterministic inputs, using state variable formulation. Block diagram representation and analysis of typical systems. Development and application of Routh-Hurwitz, Nyquist, and root-locus. Stability. Comparison of several compensation configurations for both static and dynamic performance criteria, including the effects of specific disturbances. Consideration of controllability and observability.

16-515 Nonlinear Control Systems *Staff* **(3-0)3**
Prerequisite: 16-413 or 16-513
Analytic and numerical methods for the analysis and design of non-linear control systems. Phase plane, describing function, the methods of Lyapunov and Popov and other nonlinear analysis techniques are treated.

16-517 Optimal Control Systems *Staff* **(3-0)3**
Prerequisite: 16-413 or 16-513
A study of the analysis and design of optimal control systems by dynamic programming, calculus of variations, and Pontryagin's Method.

16-519 Digital Control Systems *Staff* **(3-0)3**
Prerequisite: 16-413 or 16-513
The sampling process, reconstruction of sampled signals, z-transforms, signal-flow graph representation of digital systems. The state variable approach to discrete data systems, time solutions by state variable methods. Stability of discrete data systems. Introduction to optimal control of discrete data systems.

16-520 Numerical Computing *Staff* **(3-0)3**
Prerequisite: 16-228
Numerical algorithms fundamental to scientific computation. Elementary discussion of error, polynominal interpolation, numerical integration, solution of non-linear equations, function minimization by the method of steepest descent, numerical solution of systems of ordinary differential and difference equations with applications in the study of continuous and discrete-time dynamical systems.

16-521 Automata studies *Staff* **(3-0)3**
Prerequisite: 16-412
Mathematical foundation of automata, including probabilistic logics, neuron analog, Turing machines, and learning theory.

16-522 Data Structures *Staff* **(3-0)3**
Prerequisite: 16-328 and/or Instructor Permission
Character strings, character and character substring searches; lists, their storage structures and uses; trees, tree searches, and storage concepts;

compiling, polish strings, translating from infix to postfix and prefix, conversion to machine code.

16-523 Compiler Structures *Staff* **(3-0)3**
Prerequisite: 16-228
Translators and interpreters for programming languages. Syntax of programming languages, syntax directed compilation. Parsing techniques: operator precedence, top down, bottom up and reductive strategies. Intermediate forms and symbol tables. Generation and optimization of machine code. Error handling: detection and correction. The run time environment, storage allocation.

16-524 Programming Languages *Staff* **(3-0)3**
Prerequisite: 16-228
An introduction to the formal concepts of programming languages including specification of syntax and semantics. Examination of programming languages (FORTRAN, ALGOL, APL) and string processing languages (SNOBOL). Concepts such as information binding, data storage and mapping and basic control structures are discussed.

16-525 Simulation Techniques *Staff* **(3-0)3**
Prerequisite: 16-228, 16-445
A study of modern analog, digital and hybrid techniques for the simulation of continuous and discrete systems and processes. The student is expectBed to study a number of practical engineering systems through the use of simulation techniques on available analog, hybrid and digital computers.

16-528 Advanced Network Analysis *Staff* **(3-0)3**
Prerequisite: 16-362
Network topology, generation of circuit equations on a loop, nodal, and mixed basis, using matrix algebra. Linear independence and choosing network variables. Tellegen's theorem, reciprocity, and the properties of passive networks. Quadratic forms. Methods of handling mutual inductance, dependent sources, gyrators and the like with Thevenin's theorem, superposition, and other network theorems. Impedence by inspection and the relationship between the natural frequencies of a system and the poles and zeros of the impedence and admittance functions. The phase and magnitude relationships of various filters with precorrection for loss effects, using frequency transformations and Hilbert transforms. Butterworth and Chebyshev filters with magnitude and frequency scaling. Properties and interconnections of two-terminal pair networks and Bartlett's bisection theorem.

16-529 Network Synthesis I *Staff* **(3-0)3**
Prerequisite: 16-362
A review of natural frequencies and analysis techniques; complex variable topics such as conformal mapping, maximum modulus theorem, and Laurent series. Tellegen's theorem. Positive real (p.r.) functions developed from four different viewpoints, including reflection coefficients. Methods for testing p.r. functions; Hurwitz test, Sturm test, and residue tests. Quadratic forms and the testing for p.r. matrices. Properties of the driving point and transfer immittances of LCT, RCT, and RLT networks, Cauer and Foster network realizations, partial pole removals. Cauer transformations. RLCT Brune realizations.

16-530 Network Synthesis II *Staff* **(3-0)3**
Prerequisite: 16-529
RLCT driving-point synthesis methods of Darlington, Bott-Duffin, Miyata and Fialkow-Gerst. Transfer synthesis methods of Darlington, constant-resistance lattice, RC ladder. Approximation problems using Butterworth functions, dissipation and predistortion techniques. An introduction to active network synthesis.

16-531 Active Network Synthesis *Staff* **(3-0)3**
Prerequisite: 16-366
Definition and discussion of active network elements such as controlled sources, impedance converters, and impedance inverters. Synthesis techniques using the negative impedance converter, the gyrator, and the infinite gain amplifier will be discussed. The application of the various active elements to modern active filter design will be emphasized.

16-537 Introduction to Bio-Medical Engineering *Staff* **(3-0)3**
Prerequisite: 16-366
A survey of the use of engineering methods in the life sciences. Topics covered include instrumentation techniques and devices, computer diagnosis of disease, computer aided data analysis, telemetry, ultrasonic techniques, artificial organs, prosthetic devices, biological modeling and simulation. Necessary biological background information is introduced as needed.

16-539 Biological Systems *Staff* **(3-0)3**
Prerequisite: 16-413, 16-445, 16-537
A discussion of the application of modern control theory to the study of biological systems. Modeling and simulation techniques are emphasized. Necessary biological background information is introduced as required.

16-543 Theory of Communications *Staff* **(3-0)3**
Corequisite: 16-509
Introduction to information transmission. Representation of deterministic signals in time and frequency domains. Relationship between correlation and power or energy spectra. Introduction to statistical properties of noise. Thermal and shot noise, signal-to-noise ratio, noise figure, and noise temperature. Comparative analysis of continuous and discrete modulation systems; analysis of AM, FM, and various pulse modulation methods (PAM, PPM, PCM) in the presence of noise.

16-545 Coding Theory *Staff* **(3-0)3**
Concepts and recent developments in the use of codes for error control in data handling systems. Encoding and decoding procedures and their implementation in computational algorithms and hardware organizations are investigated in detail.

16-547 Statistical Communication Theory *Staff* **(3-0)3**
Prerequisite: 92-584 or Permission of Instructor
A study of statistical communication problems. Particular topics include the description of signals and noise as stochastic processes, optimum smoothing and prediction and statistical decision theory.

16-548 Information Theory *Staff* **(3-0)3**
Prerequisite: 92-584 or Permission of Instructor
A study of the probabilistic measure of information transmitted by information sources, the determination of the information handling capacity of communication channels and fundamental coding theorems.

16-549 Introduction to Lasers and Masers *Staff* **(3-0)3**
Prerequisite: 16-362, 16-461, or equiv.
A first course on lasers and masers and their applications. Classical electromagnetic theory as well as introductory Quantum Mechanics serve to provide background to engineering students interested in industrial and scientific laser applications. Typical topics include interferometry, liquid crystals and fiber optics, harmonic generation and holography.

16-551 Electro-Optics *Staff* **(3-0)3**
Prerequisite: 16-362, 16-461
Principles of optical propagation as described by the Fresnel-Kirchhoff Integral and the Rayleigh integral, concept of transform theory as applied to optical imaging systems, transform theory of conjugate focal plane of lenses in coherent optical systems, geometrical optics as described by Newtonian lens formulae and principles of holographic three-dimensional wave-front reconstruction.

16-561 Computer Organization and Design *Staff* **(3-0)3**
Prerequisite: 16-411, 16-417
A critical examination of the organization of present day digital computers from both the software and hardware points of view. Computer design with hardware-software trade-off. Comparison of instruction sets, their hardware implementation. Examination of the input-output structures of selected examples. Multi-processing and parallel processing. Detailed examination of a large system and of several mini-computers. Students are expected to simulate certain aspects of the example computers on available digital computers.

16-562 Microprogramming *Staff* **(3-0)3**
Prerequisite: 16-417
Microprogramming is introduced as an intermediate hierarchical level between hardware and software. A typical microprogrammable machine such as the HP 21-MX is used. A detailed study is made of data paths, timing rules, control commands available to the programmer, and what modifications and tests are performed in the process. Micro-programs are written in both machine language and in the microassembly language and are debugged interactively using the MICRO-DEBUG EDITOR. Previously written macro-language programs are reviewed and the least efficient segments are rewritten in micro-code so that execution times are reduced. User's function codes are developed to further illustrate the efficacy of writable control store operations in the extension of the computer macroinstruction set. Emphasis is placed on the fact that microinstructions have access to many internal registers and logical functions that the Main Memory programs cannot use.

16-563 System Programming *Staff* **(3-0)3**
Prerequisite: 16-417
The definition of system programming as programming in a multi-user environment. Programming with and for interrupts. Reentrant programming, pure procedures. Communication between program modules. Nested calls, the push-down stack. Recursive program calls. Reentrant interrupt programming. Activation records and program sharing. Memory allocation by absolute and relocatable loaders. Macro languages, macro processes and introduction to assemblers and macro assemblers.

16-564 Operating Systems *Staff* **(3-0)3**
Prerequisite: 16-417
The resources of a large computer system. Sequential and concurrent processes in large digital computers. Design objectives: Program sharing, Multi-processing, Memory-sharing and protection. Process communications and critical processes in operating systems. Scheduling. Paging, Segmenting and swaping strategies. Time sharing and multiple-task operating systems. Design and simulation of operating system behavior. Operating system performance evaluation.

16-571 Introduction to Radar Systems *Staff* **(3-0)3**
Prerequisite: 16-439 or 16-543
Introduction to both pulsed and C.W. radar systems. Detection of radar echoes in noise. The radar equation and its use in estimating performance of a radar system. Estimation of range, direction and velocity of targets. Moving target indicators (MTI). Pulse compression and other advanced techniques. Discussion of elements of practical radar systems.

16-572 Introduction to Microprocessors *Staff* **(3-0)3**
Prerequisites: 16-417, 16-575, 16-412 or Permission of Instructor
Microprocessor models are introduced and comparisons of the internal architecture of available microprocessors are studied. Buss architecture, timing diagrams, loading considerations, the instruction set, etc., are studied using a currently available microprocessor as an example. Support chips such as priority interrupt controllers, DMA, A/D, D/A, and programmable peripheral-interface units will be examined. Current applications of microprocessors will be studied.

16-574 Introduction to Digital System Design *Staff* **(3-0)3**
Prerequisite: 16-411, 16-417
A review of combinatorial and sequential circuit concepts at both the bit and register levels, number systems, binary adders, shift registers, and memories. The definition of a basic set of control operations and data modules that are used to develop a register-transfer-level language which is used to flowchart and document design algorithms. Computer-assisted simulations, using SIMRIM, are conducted to assist in an evaluation of the cost, performance, and adaptability of each design algorithm. Applications include asynchronous processing, parallel processing, stacks, queues, microprocessing, special purpose processors, and microcoded processors.

16-575 Digital Subsystem Design *Staff* **(2-2)3**
Prerequisite: 16-574
An overview of the design process developed in EE 574 with emphasis on developing algorithms at the register transfer level, decomposition of these algorithms into detailed RTL flowcharts showing registers, transfer paths, control and timing paths. Selected flowcharts are converted to a detailed wiring diagram for wire-wrap testing and study. A hardware term project is required of each student, constructed from the available register transfer module family along with a complete report detailing the scope and purpose of the algorithm.

16-577 State Variable Analysis of Systems *Staff* **(3-0)3**
Prerequisite: 16-362
Algebra of matrices, vector spaces, and linear transformations. Calculus of matrices, matrix functions and the solution of differential and differ-

ence equations as formulated by the state variable characterization of systems. A consideration of canonical forms for computer simulation.

16-581 Electrodynamics *Staff* **(3-0)3**
Prerequisite: 16-355
The main focus of this course is the transient analysis of electromechanical devices, including electromechanical transducers and ac and dc machines. Topics covered include stored electric and magnetic energy, electric and magnetic forces, dynamic models of electromechanical devices, solution of differential equations to obtain equations of motion, driving point impedances, transfer functions for linear devices, and methods of approximation for non-linear devices. Applications covered include magnetic transducers, piezo-electric transducers, transient analysis of power systems, and the formulation of mathematical models of servo-mechanism components.

16-601 Seminar in Electrical Engineering *Staff* **(3-0)3**
Prerequisite: Minimum of 15 credit-hours of Graduate Courses
The purpose of the seminar is to provide students in the non-thesis option with the opportunity to satisfy the requirement of making a scholarly oral presentation before a group in his field, primarily composed of his class and instructor. Early in the course student proposals will be heard and, if necessary, modified or redefined. Acceptable subjects will include but will not be limited to selected topics in the general field of electrical engineering, lucid descriptions and reviews of compactly written technical journal articles, individual or original topics. Each student will be judged on his clarity of exposition, his knowledge of his subject, his ability to clearly and effectively answer questions, as well as his own participation in the discussions of other papers. Letter grades will be issued (A, B, C, etc.). The class size will be limited to ten students and will meet 3 hours per week for one semester.

16-651 Selected Topics in Electrical Engineering *Staff* **(3-0)3**
Prerequisite: Specified at the time of a particular offering
Advanced topics in various areas of electrical engineering and related fields. Since topical coverage varies from term to term, a student may be allowed to receive credit more than once for this course.

16-701 Graduate Research in Electrical Engineering *Staff* **(0-9)6**
Prerequisite: Minimum of 15 credit hours of Graduate Courses
Analytical and/or experimental work conducted under the supervision of a faculty member of the Department of Electrical Engineering leading to a written report in the form of a thesis, an oral presentation, and a defense of this thesis on some problem in the area of electrical engineering.

12-701 Graduate Research in Computer Engineering *Staff* **(0-9)6**
Prerequisite: Minimum of 15 credit-hours of Graduate Courses
Analytical and/or experimental work conducted under the supervision of a faculty member of the Department of Electrical Engineering leading to a written report in the form of a thesis, an oral presentation, and a defense of this thesis on some problem in the area of computer engineering.

28-701 Graduate Research in Systems Engineering *Staff* **(0-9)6**
Prerequisite: Minimum of 15 credit-hours of Graduate Courses
Analytical and/or experimental work conducted under the supervision of a faculty member of the Department of Electrical Engineering or perhaps another department in the case of an interdisciplinary program, leading

to a written report in the form of a thesis, an oral presentation, and a defense of this thesis on some problem in the area of systems engineering.

DEPARTMENT OF ENERGY ENGINEERING*

Department Chairperson: James P. Phelps, *Professor;* B.S., University of Maine; Ph.D., Michigan State University.

Graduate Coordinator: Jose G. Martin, *Professor;* B.S., Mississippi State University; M.S., Ph.D., University of Wisconsin.

Faculty

Gilbert G. Brown, *Associate Professor;* B.S., Cornell University; M.S., Ph.D., Massachusetts Institute of Technology.

William L. Filippone, *Associate Professor;* B.S., University of Notre Dame; Ph.D., University of Maryland.

James R. Sheff, *Associate Professor;* B.S., University of Colorado; M.S., Ph.D., University of Washington.

*Formerly Nuclear Engineering

Facilities

The Energy Center houses some major engineering research facilities including a 1-Mw swimming pool research reactor, a 5-MeV Van de Graaf accelerator, and a solar collector testing facility.

The University has an inventory of solar equipment including several solar collectors.

There is alo CDC CYBER-71 computer with 98K word core memory and extensive time-sharing capability.

Research

Research in Energy Engineering is carried out by several of the engineering departments in the College of Engineering.

Research interests include energy economics and safety, particle transport theory, radiation damage, controlled nuclear fusion, solar energy development, geothermal and wind energy utilization, cross section measurement, numerical analysis, fast reactors, nuclear fuel management, nuclear waste disposal, denatured fuel cycles, coal technology, power transmission, direct energy conversion.

Master of Science Degree Program

The graduate program in Energy Engineering offers professional training at the master's degree level designed to provide the opportunity for the student to broaden and deepen his knowledge of various energy systems.

Credit Requirements and Thesis
Participants in the program may elect to follow a thesis or non-thesis option. The thesis option requires a minimum of 30 credit hours; 18-24 credit hours of course work plus 6-12 credit hours of thesis research. The non-thesis option requires a minimum of 33 credit hours; 27-30 credit hours of course work plus 3-6 credit hours of 24-701,702. A thesis must be defended in an oral examination conducted by the student's thesis committee.

Course Requirements
Students may choose to specialize in any area of energy of interest in the College. The areas of fission, fusion, solar, and geothermal energy are listed as examples. Each student must take a series of five core courses appropriate for his area of specialization. The exact makeup of the core curriculum will be guided and approved by the Graduate Committee. Typical courses for the various areas of concentration are as follows:

Fission
24-505 Reactor Theory I
24-506 Reactor Theory II
24-507 Power Systems Engineering I
24-508 Power Systems Engineering II
24-525 Numerical Methods of Engineering Analysis

Fusion
24-415,416 Introduction to Fusion Research
24-515 Controlled Nuclear Fusion I
24-516 Controlled Nuclear Fusion II
24-525 Numerical Methods of Engineering Analysis
24-505 Reactor Theory and Analysis I

Solar
24-425 Introduction to Solar Energy
24-513 Advanced Solar Energy
24-508 Power Systems Engineering II
22-546 Energy Conversion
24-525 Numerical Methods of Engineering Analysis

Geothermal Energy
24-529 Geothermal and Wind Energy
24-530 Geothermal Analysis and Theory
24-508 Power Systems Engineering II
10-528 Intermediate Transport Phenomena
24-525 Numerical Methods of Engineering Analysis

The remainder of the credit requirements are to be made up of elective courses determined by the student and his adviser. (The adviser may be chosen from any engineering department.) Elective courses are not restricted to those courses offered by this Department.

In addition to the course and credit requirements described above, all master's students are expected to participate in the Graduate Research Seminar, 24-501,502.

Five Year Master of Science Program in Energy Engineering (Fission Option Only)

I. For students wishing to pursue the five year B.S./M.S. program, the first three years of course work is the same as that specified for students in the four year Bachelor's program.

II. In the senior year, the following modifications are involved:
   A. Students would substitute the graduate sequence in Power Systems Engineering, 24-507,508 (6 credits) for the undergraduate sequence 24-401,402 (also 6 credits).
   B. The graduate sequence in Reactor Theory and Analysis would be taken:
      1. As an overload, or
      2. As elective course work.

   The senior year would be as follows:

24-507	Power Systems Engineering I	3
24-403	Reactor Operations and Licensing	3
24-416	Introduction to Fusion Design	3
24-505	Reactor Theory and Analysis	3
	Undesignated Elective	3
	Technical Elective (optional overload)	(3)
		15 or 18
24-508	Power Systems Engineering II	3
24-404	Power Systems Design	4
24-506	Reactor Theory and Analysis	3
	Undesignated Elective	3
	Technical Elective	3
	Technical Elective (optional overload)	(3)
		16 or 19

III. The students receive their B.S. degree after completing their senior year.

IV. The students should be in a position to start a master's thesis or project in summer following their senior year.

V. The fifth year will consist of graduate course work and completion of a thesis or project.
   A. Since the graduate Power Systems Engineering courses are taken in the senior year the credit requirements for the M.S. degree will be reduced from 30 credits to 24 (6 to 12 credits of which can be thesis credit) for the thesis option, and from 33 to 27 (3 to 6 credits of which can be project credits) for the non-thesis option.
   B. If the overloads are taken in the senior year, then the Reactor Theory courses count for graduate credit. In this case, the minimum number of credits needed in the fifth year would be 18 for the thesis option and 21 for the non-thesis option.
   C. The Power Systems Engineering and Reactor Theory and courses taken during the senior year must satisfy the minimum grade requirements set by the Graduate School in order to count toward the M.S. degree.

Ph.D. Program

A program offering a Ph.D. in Applied Physics with a concentration in energy technology is offered jointly by the departments of Physics and Energy Engineering. The program is designed to develop advanced competence in physics and to provide professional training in engineering. A (diagnostic) written Comprehensive Examination in fundamental undergraduate physics (classical mechanics, electricity and magnetism, and, as appropriate, thermo-dynamics, statistical mechanics, quantum mechanics, modern physics) is to be taken upon entry to the first semester of the graduate doctoral program by students with a baccalaureate degree in physics, and by the third semester of the graduate doctoral program by non-physics majors. Later an oral examination (the Doctoral Admission Examination) based upon two semesters of#751/752 Advanced Research Projects and any graduate courses that have been taken up to that time is given as a test of acceptance into the research leading to the submission of a Ph.D. thesis.

The program is structured as follows:

1. *General Required Courses*

Demonstration of competency in the following undergraduate level physics core courses, or their equivalents, is required, in

addition to a comprehensive knowledge of introductory physics:

95-513 Classical Mechanics
96-553/4 Electricity and Magnetism I/II
95-535/6 Quantum Mechanics I/II

If needed, these normally would be taken (for graduate credit by baccalaureate degreed non-physics majors) during the first four semesters of their graduate program. In addition, a graduate sequence of two courses in the mathematics of physics or engineering is required, together with 6 or 8 credits from among the following courses, or their equivalents, as appropriate for each particular concentration:

95-511-522 Classical Mechanics, and
Statistical Mechanics and Thermodynamics
95-515/6 Quantum Mechanics I/II
95-517/8 Advanced Quantum Mechanics I/II
95-557/8 Electromagnetic Theory I/II

Students with a B.S. degree in Physics entering the Ph.D. program in an Applied Physics concentration cannot obtain graduate credit for 95-513, 95-553/4, or 95-535/6; they would be expected to take at least two of the above course sequences.

In addition, the following courses in Energy Engineering are required:

A. *Fission Option*
(a) 24-505/6 Reactor Theory I & II
(b) 24-507/8 Power Systems Engineering I & II
(c) Two Energy Engineering Electives

B. *Fusion Option*
(a) 24-416 Introduction to Fusion
(b) 24-515/6 Controlled Fusion I & II
(c) 80-455 Plasma Physics
(d) Two Energy Engineering Electives

C. *Solar Option*
(a) 24-525/6 Solar Energy I & II
(b) 22-546 Energy Conversion
(c) 24-508 Power Systems Engineering II
(d) Two Energy Engineering Electives

D. *Geothermal Option*
(a) 24-529 Geothermal & Wind
(b) 24-530 Geothermal Analysis
(c) 89-461 Geophysical Survey
(d) 24-508 Power Systems Engineering II
(e) Two Energy Engineering Electives

Typical schedules for the respective concentrations are as follows:

(A) *Fission Option*

Semester I		*Semester II*	
95-513 Classical Mechanics	(4)	24-525 Numerical Methods	(3)
95-553 Electricity & Mag. I	(3)	95-554 Electricity & Mag. II	(3)
24-505 Reactor Theory I	(3)	24-506 Reactor Theory II	(3)

Comprehensive Examination

Semester III		*Semester IV*	
24-526 Adv. Engineering Math	(3)		
24-507 Power Systems Eng. I	(3)	24-508 Power Systems Eng. II	(3)
95-535 Quantum Mechanics I	(3)	95-536 Quantum Mechanics II	(3)
95-751 Adv. Project in Phys. I	(3)	95-752 Adv. Project in Phys. II	(3)

Doctoral Research Admission Examination

(B) *Fusion/Plasma Option*

Semester I		*Semester II*	
95-513 Classical Mechanics	(4)	24-525 Numerical Methods	(3)
95-553 Electricity & Mag. I	(3)	95-554 Electricity & Mag. II	(3)
24-416 Introduction to Fusion	(3)	80-455 Plasma Physics	(3)

Comprehensive Examination

Semester III		*Semester IV*	
95-535 Quantum Mechanics I	(3)	95-536 Quantum Mechanics II	(3)
24-526 Adv. Engineering Math	(3)		
24-515 Controlled Fusion I	(3)	24-516 Controlled Fusion II	(3)
95-751 Adv. Project in Phys.	(3)	95-752 Adv. Project in Phys. II	(3)

Doctoral Research Admission Examination

(C) *Solar Energy Option*

Semester I		*Semester II*	
95-513 Classical Mechanics	(4)	24-525 Numerical Methods	(3)
95-553 Electricity & Mag. I	(3)	95-554 Electricity & Mag. II	(3)
24-425 Intro. to Solar Energy	(3)	25-518 Adv. Solar Energy	(3)

Comprehensive Examination

Semester III		*Semester IV*	
95-535 Quantum Mechanics I	(3)	95-536 Quantum Mechanics II	(3)
22-546 Energy Conversion	(3)	24-508 Power Systems Eng. II	(3)
95-421 Stat. Thermodynamics	(3)		
95-751 Adv. Project Physics I	(3)	95-752 Adv. Project Phys. II	(3)

Doctoral Research Admission Examination

(D) *Geothermal Option*

Semester I		*Semester II*	
95-413 Classical Mechanics	(4)	24-525 Numerical Methods	(3)
95-553 Electricity & Mag. I	(3)	95-554 Electricity & Mag. II	(3)
24-529 Geothermal & Wind Ener.	(3)	24-530 Geothermal Analysis	(3)

Comprehensive Examination

Semester III		*Semester IV*	
95-535 Quantum Mechanics I	(3)	95-536 Quantum Mechanics II	(3)
24-525 Adv. Engineering Math.	(3)	24-508 Power Plant Eng. II	(3)
89-461 Geophysical Survey	(3)		
95-571 Adv. Project in Phys.	(3)	95-572 Adv. Project in Phys. II	(3)

Doctoral Research Admission Examination

Language Requirement
A demonstration of proficiency adequate for reading technical articles in physics (level two) in French, German, Russian, Spanish, or Italian.

Other Skills
Either (a) a demonstration of reading proficiency (level two) in a foreign language from among French, German, or Russian in addition to that used for the language requirement, or (b) a demonstration of proficiency in computer programming, which may be validated by achieving a grade of B or higher in 24-397 Numerical Methods of Eng. Design, or 80-397, Computer Programming and Applications I, or by demonstrating equivalent competence.

Thesis Requirements
A thesis proposal must be approved by a joint committee of the two departments. The thesis is to be based on original research performed under the supervision of a member of the graduate faculty holding an earned Ph.D. degree, and written to conform to the requirements of the Graduate School. Four legible copies of a typewritten original must be submitted. Following this, the student must pass an oral examination conducted by his/her thesis committee, based on, but not necessarily limited to, his/her thesis.

DEPARTMENT OF MECHANICAL ENGINEERING

Department Chairperson: C. Zelman Kamien, *Associate Professor;* B.S., M.S., Ph.D., Purdue University.

Graduate Coordinator: John A. McElman, *Professor;* B.S., M.S., Northeastern University; Ph.D., Virginia Polytechnic Institute.

Faculty

William Kyros, *Associate Professor;* B.S., University of Lowell; M.S., Massachusetts Institute of Technology; Ph.D., Cornell University.

Alan Mironer, *Professor;* B.M.E., Rensselaer Polytechnic Institute; M.Eng., Yale University; Ph.D., Syracuse University.

Eugene E. Niemi, Jr., *Associate Professor;* B.S., Boston University; M.S., Worcester Polytechnic Institute; Ph.D. University of Massachusetts.

John C. O'Callahan, *Associate Professor;* B.S., M.S., Ph.D., Northeastern University.

Roy Richard, II, *Instructor;* B.S., Lowell Technological Institute; M.S., Catholic University of America, Washington, D.C.; Ph.D., Tufts University.

Steven Serabian, *Professor;* B.S., Rensselaer Polytechnic Institute; M.S., Union College.

G. Dudley Shepard, *Professor;* B.S., Yale University; S.M., Sc.D., Massachusetts Institute of Technology.

Yakov Zilberberg, *Instructor;* M.S., Technical Institute, Odessa, U.S.S.R.

Master of Science Degree Program

The Department of Mechanical Engineering offers a program leading to the master's degree. The program consists of a total of at least thirty semester hours of work, including a thesis of at least six semester hours' credit. Under special circumstances, a nonthesis option may be permitted upon petition by the student. This option consists of at least 33 semester hours of course work which must include 3 credits of 22-701 Graduate Research in Mechanical Engineering or 22-702 Advanced Projects in Mechanical Engineering.

Students who are deficient in their prior training will be required to take certain undergraduate courses without graduate credit.

Prior to the student's first graduate registration, each candidate for the degree will be interviewed by representatives of the graduate faculty for the purpose of being assigned an advisory committee. This committee will work with the candidate to outline a program of course work which will fit his/her specific needs and goals. The candidate is required to submit a thesis proposal which must be approved by his/her advisory committee prior to initiating a thesis research.

The program of each candidate is subject to review and revision at any time and may be modified to take account of the availability of specific courses, changes in the student's needs and goals, or for other good reasons, as determined by the student's advisory committee.

Advanced Research

A major funded research program in Mechanical Engineering involves the study of the dynamics of structures under random load inputs. An extensive computer program RAND has been developed. A follow-up experimental program is under way. Other research efforts include nondestructive testing of materials by ultrasonic technique, and the study of the offshore oil spill problem.

Retention Standards

Each student is expected to perform satisfactorily in his graduate work: 6 credits of BC and/or C together with a cumulative average of less than 3.0 will result in probation, i.e., reclassification from matriculated to provisional status. Twelve or more credits of BC and/or C together with a cumulative average of less than 3.0 will result in the student's being dropped from the graduate program.

Five Year Master of Science Program

I. For students wishing to pursue the five year BS/MS program, the first three years of course work is the same as that specified for students in the four year Bachelor's program.

II. In the senior year, the following modifications are involved.
   A. Students should take one graduate course per semester.
   B. Students should start their preliminary work on the thesis and this work will also satisfy the senior project course requirements (22-407 and 22-408).
   C. The thesis adviser acts as the senior project supervisor.
   D. The students receive their B.S. degree after completing their senior year.
   E. In the fifth year, students take three graduate level courses per semester as well as 3 thesis credits per semester.

Ph.D. Program

A program offering a Ph.D. in Applied Physics with a concentration in Applied Mechanics is offered jointly by the department of

Physics and Mechanical Engineering. The program is structured as follows:

1. *General Required Courses*
   (a) Undergraduate courses include two semesters of Junior Electricity & Magnetism and two semesters of Junior Quantum Mechanics.
   (b) Graduate courses include two semesters of Mathematical Physics, one semester of Classical Mechanics and one semester of Thermodynamics & Statistical Mechanics.

2. *Qualifying Examination*
   The student must pass a comprehensive examination in Junior Mechanics, Electricity and Magnetism, and Quantum Mechanics after completion of part a.

3. *Thesis Requirements*
   A thesis proposal must be approved by a joint committee of the two departments. A student may not register for Graduate Research until he has passed the Ph.D. qualifying examination and the thesis proposal is approved. The thesis is to be based on original research performed under the supervision of a member of the graduate faculty and written to conform to the requirements of the Graduate School. Four legible copies of a typewritten original must be submitted to the Physics Department. Following this, the student must pass an oral examination, based on, but not necessarily limited to the thesis.

Courses of Study

22-511/22-582 Matrix Method in Engineering Mechanics *O'Callahan* **(3-0)3**

Development of matrix methods of analysis as applied to engineering mechanics. Methods include determining eigenvalues and eigenvectors using direct and iterative techniques; solution of large sets of algebraic equations using direct reduction techniques such as CROUT, CHOLESKY and GAUSS-DOOLITTLE schemes; FORTRAN programs involving the methods will be written for the digital computer; problems will involve development of mass and stiffness matrices for structural systems, involving vibrations and stability. Problems will be solved using the MATRIX Computer Program.

22-512/22-564 Structural Dynamics *O'Callahan* **(3-0)3**

Review of matrix operations, development of the equations of motion of a single and multi degree of freedom systems. Development of stiffness, mass and damping matrices. Condensation of equations by stiffness condensation and GUYAN reduction. Modal analysis techniques to encouple equations of motion. Direct integration of the motion equations. Discus-

sion of proportional and non-proportional damping. Applications using computer programs such as MATRIX and SAPIV to solve problems in structural dynamics.

22-513/22-262 Advanced Dynamics *McElman* **(3-0)3**
Dynamics of mechanical systems by use of direct and variational methods. Three-dimensional rigid body dynamics and vibrations of lumped parameter and continuous systems. Non-linear and self-excited oscillations. Stability.

22-518/22-558 Plates and Shells *McElman* **(3-0)3**
Variational methods are utilized to derive the plate and shell equilibrium equations including non-linear effects and inertia terms. Solutions to bending, buckling and vibration problems are obtained for rectangular and circular plates. The membrane theory of shells as well as the general theory is investigated and solutions are obtained for a variety of practical shell problems.

22-542/22-531 Advanced Thermodynamics *Zilberberg* **(3-0)3**
A comprehensive treatment of the classical first and second law. Availability, criteria of equilibrium, heterogeneous systems, mixtures and solutions, chemical equilibrium. Introduction to statistical methods as applied to evaluation of thermodynamic properties.

22-543/22-534 Transport Processes *Zilberberg* **(3-0)3**
Diffusive and convective transport of mass, momentum and energy. Forced convection in laminar and turbulent flows. Heat and mass transfer accompanied by change of phase and chemical reactions.

22-544/22-535 Advanced Heat Transfer *Yeung* **(3-0)3**
Heat conduction: analytical and numerical solutions, laws of thermal radiations, combined modes of heat transfer, heat transfer in the environment and in biological systems. Thermal pollution.

22-545/22-536 Combustion *Kamien* **(3-0)3**
Dynamics of premixed and diffusion flames: ignition and extinction, burning of liquid and solid fuels, radiation from flames, fire problems.

22-546 Energy Conversion *Kamien* **(3-0)3**
Concepts of thermodynamics pertaining to energy conversion; irreversible thermodynamics. Solid-state phenomena involved in conversion processes; energy forms, equations of states and energy fields. Selected topics in direct energy conversion systems.

22-553/22-566 Random Vibration *Shepard* **(3-0)3**
Random processes: probability, time and ensemble averages, correlation and power spectra. Stationary and radom vector excitation of single and multi degree-of-freedom dynamic systems. Use of computer program RAND to study statistically coupled base and pressure excitations of continuous structures.

22-554/22-572 Dynamic Systems and Control *Shepard* **(3-0)3**
Classical and modern approaches to the dynamics of systems with multiple inputs and outputs. State equations for hydraulic, penumatic, electromechanical, and thermal systems using the state function of Lagrange. Analytical approach to system response in physical and modal domains. Introduction to simulation and to digital control.

22-562/22-551 Continuum Mechanics *Yeung* **(3-0)3**
Stress and deformation in a continuum in tensor notation. Fundamental

laws of mechanics and thermodynamics. Application to elastic viscous and viscoelastic substances.

22-563/22-553 Finite Element Analysis *O'Callahan* **(3-0)3**
A review of matrix algebra and calculus to develop the finite element equations in structural and thermal systems. Review of stress, strain and constitutive equations of solids. Develop mass and stiffness matrices for truss, frames 2D and 3D solids. A large finite element computer program (SAPIV) will be used to solve problems in structural mechanics. Non steady heat conduction problems will also be studied using finite element techniques.

22-565/22-581 Engineering Analysis *Shepard* **(3-0)3**
A study of the methods used in engineering with emphasis dependent upon the instructor. Topics include matrix methods, variational methods, finite differences, orthogonal series, and the Ritz and Galerkin methods for solving differential equations. Problems include systems encountered in solid mechanics, heat transfer and fluid mechanics.

22-566/22-556 Theory of the Inelastic Continuum *McElman* **(3-0)3**
Development of the constitutive equations governing inelastic (anelastic, viscoelastic, plastic and visco-plastic) deformations. Theorems and boundary value problems as applied to inelastic continua.

22-568/22-554 Theory of Elasticity *McElman* **(3-0)3**
Prerequisite: 22-562
Formulation of the problem of elastic equilibrium. Torsion and flexure of prismatic bars, contact stresses, plane stress, plain strain and stress concentration.

22-581/22-541 Advanced Fluid Mechanics *Mironer* **(3-0)3**
Review of fundamental equations of fluid motion, Kinematics, vorticity, circulation, Crocco's theorem, Kelvin's theorem, Helmholtz's vorticity laws, secondary flows, Stream function, velocity potential, potential flow, unsteady Bernoulli equation, gravity water waves. Navier-stokes equations; introduction to statistical theory of turbulence, Reynolds stresses.

22-582 Viscous Flow *Yeung* **(3-0)3**
Review of Navier-Stokes equations. Examples of exact solutions. Boundary-layer approximation. Similarity analysis of boundary layer flows. Introduction of computational fluid dynamics. Compressibility effect: Stewartson transformation. Stability of boundary layer and introduction to turbulence.

22-583/22-548 Advanced Topics in Aerodynamics *Niemi* **(3-0)3**
Prerequisite: 22-483
Application of aerodynamic principles to one or two of the following topics: aircraft performance analysis, stability and control, orbital mechanics, or helicopter rotor aerodynamics (including propellers and wind turbines). Topics vary from year to year depending on current departmental research interests.

22-587/22-542 Advanced Gas Dynamics *Mironer* **(3-0)3**
Equations of motion for inviscid, compressible fluid. One-dimensional steady flow with area change, friction, heat transfer and combustion. Shock waves. Unsteady flows and wave phenomena. Similarity characteristics, small disturbances, approximation procedures.

22-591/22-521 Mechanical Behavior of Materials *Serabian* **(3-0)3**
Prerequisite: 22-495
An examination of deformation mechanisms in solids and the study of such topics as brittle and ductile modes of fracture fatigue, creep, viscoelasticity, diffusion, friction and wear using actual case studies of failures.

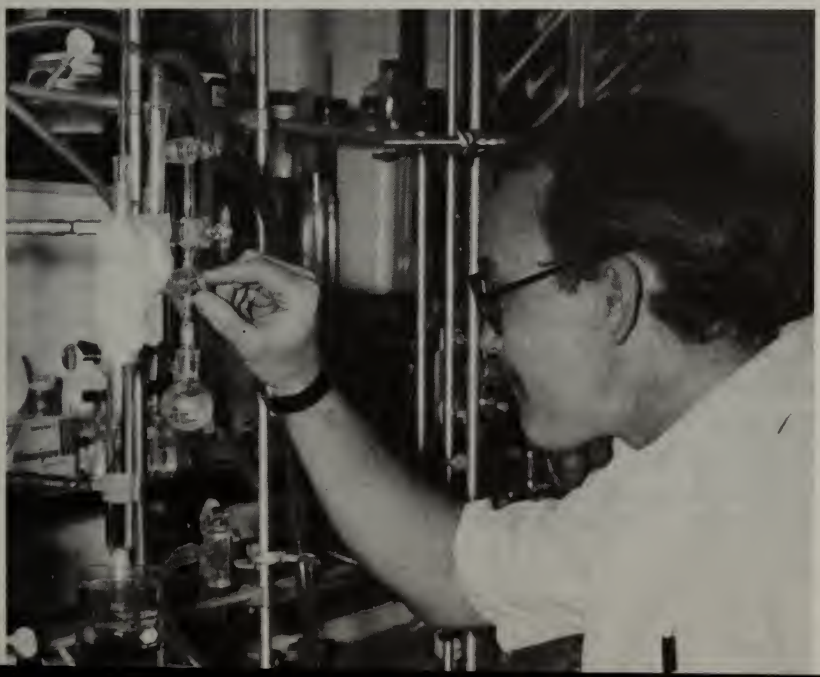
22-592/22-530 Ultrasound, a Nondestructive Evaluation Method *Serabian* **(3-0)3**
Propagation characteristics of ultrasound are developed and analyzed to indicate usefulness as a nondestructive method of evaluation. Equipment for generation, detection and display. Scientific and engineering applications using velocity and attenuation measurements are stressed.

22-597/22-552 Structural Application of Composite Materials *McElman* **(3-0)3**
Study of constitutive relationships for anisotropic materials and application of these materials to structural elements such as beams, plates and shells. Problem areas considered include bending, buckling, and vibrations.

22-601/22-651 Selected Topics of Mechanical Eng. *Staff* **(3-0)3**
Advanced topics in the various fields of mechanical engineering. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary mechanical engineering.

22-701 Thesis Research in Mechanical Engineering *Staff* **(0-9)3**
Prerequisite: Permission of Adviser
Introduction to the methods of contemporary mechanical engineering research. Open only to students who are concurrently engaged in thesis or project research.

22-702/22-751 Advanced Projects in Mechanical Engineering *Staff* **(0-3)2**
Prerequisite: Permission of Department
Independent reading and investigation of a particular topic of current interest in mechanical engineering.



DEPARTMENT OF PLASTICS ENGINEERING

Department Chairperson: Nick R. Schott, *Professor;* B.S., University of California, Berkeley; M.S., Ph.D., University of Arizona.

Graduate Coordinator: Rudolph D. Deanin, *Professor;* A.B., Cornell University; M.S., Ph.D., University of Illinois.

Faculty

Everett S. Arnold, *Associate Professor;* B.S., Southeastern Massachusetts University; M.S., Lowell Technological Institute.

Aldo M. Crugnola, *Professor and Dean of College;* A.B., Boston University; M.S., Northeastern University, Sc.D., Massachusetts Institute of Technology.

Stephen B. Driscoll, *Associate Professor;* B.S., M.S., Lowell Technological Institute.

Raymond O. Normandin, *Professor;* A.B., St. Anselm's College; M.S., Boston College.

Stephen A. Orroth, Jr., *Associate Professor;* B.S., M.S., Lowell Technological Institute.

Stephen P. Petrie, *Assistant Professor;* B.S., M.S., Lowell Technological Institute; Ph.D., University of Connecticut.

Clarence J. Pope, *Professor;* B.S., Clemson University; M.S., Lowell Technological Institute.

Amad Tayebi, *Associate Professor;* B.S., Alexandria University; M.S., M.E., Sc.D., Massachusetts Institute of Technology.

Master of Science Degree Program

The graduate program in plastics offers professional training at the Master of Science level designed to provide the opportunity for the study of more advanced plastics theory and practice, and to broaden the background of experienced members of the profession and to help them keep up with the latest fundamental developments in the field.

Admission Requirements

Admission to the program is open to candidates with a B.S. in plastics or a related field. Candidates with degrees in other fields, from other schools, or industrial experience in place of University of Lowell B.S. courses in plastics will take the undergraduate courses they lack as prerequisites before undertaking the graduate courses in plastics. The G.R.E. Aptitude test is required for this program, but not the Advanced test.

Combined B.S./M.S. Degree Program

In order to encourage outstanding undergraduate students to continue their studies toward an advanced degree, the College of

Engineering and the Graduate School have established a program of accelerated study which leads to a master's degree in Plastics Engineering.

To be eligible to enter this course of study, the student must file a formal Graduate School application in the junior year. This does not require the student to take a GRE examination.

Students taking full advantage of the combined program ordinarily would be expected to finish the M.S. degree at the end of the fifth year of study. However, this will depend upon the student's course load and thesis work. A more detailed description of this program is found in the beginning of this catalog.

Students admitted to the program will be allowed to use 8 credits taken in the senior year toward their M.S. degree. The 8 senior credits would come from the following sequence:

Fall Semester
26-411 Senior Seminar: Take 26-601 Graduate Seminar instead.
Undesignated Elective: Take Graduate plastics elective.

Spring Semester
26-412 Senior Seminar: Take 26-602 Graduate Seminar instead.
Undesignated Elective: Take Graduate plastics elective.

During the summer preceding the fifth year the student is expected to start his/her thesis research. The student then can complete 16 credits of electives and 6 credits of research during the fifth year and use the summer months to complete thesis work if necessary.

Students with a light load in the senior year could take more graduate courses and/or thesis work during that year, thus further accelerating their program.

Advisory Committee
Each student is assigned a faculty Advisory Committee by the department Chairperson to provide guidance in the selection of courses and in the development of a study plan which will fit his specific needs and goals. When the study plan includes a thesis, the Advisory Committee also serves as thesis committee, with the director of the thesis research project serving as the chairman of the committee. Normally, the chairman of the student's Advisory Committee is a member of the Plastics Graduate Faculty whose technical interests and research parallel those of the student. The membership of the student's committee may be changed as his area of specialty becomes more clearly defined.

Thesis or Project

A candidate for the degree of Master of Science in Plastics must complete either a thesis based on the results of original research, or a project which consists of scholarly investigation such as a review, synthesis, or design in the student's field. The Department Chairman, considering the needs of the student and the recommendation of the student's Advisory Committee, will determine whether the student should complete a thesis or a project. A proposal, which describes the nature and extent of the thesis or project that the student expects to complete, must be submitted to his Advisory Committee for approval.

Credit Requirements

A minimum of 30 semester hours is required of all students who are candidates for the M.S. degree. These should include at least 12 semester hours of courses in plastics, 2 semester hours in plastics seminar, and not more than 12 semester hours in minor subjects in related departments. Students whose program includes a thesis may receive 6 to 12 semester hours' credit for this work; those whose program includes a project may receive up to 3 semester hours' credit for it.

Elective Courses

Through proper choice of elective courses, the overall program leading to the Master of Science degree in Plastics can be specifically designed to meet the particular needs and goals of the individual student. The overall program of each student, including the thesis or project, must be approved by the student's committee, the Department Chairman, and the Dean of the graduate school. Normally the program is formulated soon after the student is fully admitted into the Graduate School. This program is subject to review and revision at any time and may be modified to take into account the availability of specific courses, changes in the student's needs or goals, or for other good reasons.

Manmade Fiber Option

This more specialized course of study is designed to prepare prospective M.S. candidates for careers in the fiber producing, the fiber processing, and the fiber reinforced plastics industries.

Admission to the program is open to students with an undergraduate degree in plastics, textiles, or other applicable field of study (mechanical or chemical engineering, applied physics or chemistry). The student's Advisory Committee will review his individual background to determine any further necessary prerequisites.

The curriculum includes 16 units of common/core courses, 2 units of seminar, 8 units of suggested electives and a 6-unit thesis in an area of current interest to the synthetic fiber industries.

Core Courses (16 Units)

97-503	Advanced Polymer Science I	(3-0)3
97-505	Polymer Preparation and Characterization I	(0-4)1
26-503	Mechanical Behavior of Polymers	(3-0)3
26-504	Polymer Proc./Morphology Properties	(3-0)3
26-515	Theory/Technology of Fiber Spinning	(3-0)3
26-525	Processing of Synthetic Fibers and Fiber Structures	(2-2)3

Elective Courses (8 units)

26-506	Polymer Structure/Properties/Applications	(3-0)3
26-516	Reinforced Plastics/Composite Materials	(3-0)3
26-519	Polymer Characterization	(3-0)3
26-526	Adv. Proc. Synthetic Fibers and Fiber Structures	(3-0)3
26-527	Mechanics of Fibrous Structures	(3-0)3
26-528	Knitted and Non-Conventional Fiber Structures	(2-2)3
26-529	Fiber Evaluation	(2-2)3
26-530	Intro. Fiber Market/Management Plant Organization	(3-0)3

Coatings Option

A complete curriculum in Coatings is offered as an option to the M.S. Plastics program. This option is open to graduates in chemistry, chemical engineering, coatings, or plastics, with experience or interest in the coatings field. The following curriculum is recommended:

26-533/4	Coatings Science and Technology I and II	(3-0)(3-0)6
97-503/4	Advanced Polymer Science I and II	(3-0)(3-0)6
97-505/6	Polymer Preparation and Characterization I and II	(0-4)(0-4)2
26-503	Mechanical Behavior of Polymers	(3-0)3
26-536	Rheology	(3-0)3
26-532	Adhesives and Adhesion	(3-0)3
26-601/2	Seminar	(1-0)(1-0)2
26-701/2	Graduate Research: Thesis	(0-9)(0-9)6

Considering the varying background and interests of individual students, this basic curriculum can of course be modified by agreement between the student and his Advisory Committee.

Doctor of Philosophy Degree Program

Students may elect the Polymer Science/Plastics Engineering

Ph.D. Program. This doctoral program is organized jointly with the Department of Chemistry. The program is designed to provide students with a background in advanced course work and laboratory techniques that will prepare them to carry out an original investigation leading to an acceptable contribution to the body of contemporary knowledge in the fields of macromolecules or plastics.

Plan of Program

The doctoral degree normally requires from three to four years of full-time study beyond the bachelor's degree or a minimum of two to three years of full-time study beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through conference with his/her Advisory Committee (or temporary advisor).

All students entering the program must take the ACS Graduate Level placement examinations in organic, physical and analytical chemistry. An evaluation examination in polymer science is given to those who wish to be exempted from 97-503/504.

Requirements for Admission, Language and Area Examinations

Requirements for admission into the program are the same as for students entering other Ph.D. programs in Chemistry. It is the student's responsibility to satisfy any admission requirements stipulated for the Ph.D. in chemistry.

Language and Area Examination requirements are the same as those for students in the Ph.D. Programs in Chemistry and may be found in this catalog under that Program.

Course Requirements

Of the 45 minimum credit requirements a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with a minimum of four courses to be taken in chemistry and polymer science (84 and 97 prefixes). The remaining course credits may be taken in the courses listed below. Credit normally is not allowed for undergraduate subjects in chemistry except for those so designated in the catalog. Research credits would then make up the remainder of the 45 credit requirement. The program of courses is the responsibility of a student's advisory committee and must include advanced subjects in the appropriate areas of chemistry, polymers, and plastics. When it is necessary to carry less than the normal credit load of 8 per semester, the student must apply to the chairman of the department through the chairman of his/her advisory committee for approval.

Required Courses
The student must take the following core courses:

84-523	Organic Reactions	(3)
	or	
84-568	Structural Analysis	(3)
84-531	Advanced Physical Chemistry	(3)
97-503	Advanced Polymer Science I	(3)
97-504	Advanced Polymer Science II	(3)
97-505	Polymer Preparation & Characterization I	(1)
97-506	Polymer Preparation & Characterization II	(1)
97-512	Bulk Properties of Polymers	(3)
	or	
26-503	Mechanical Behavior of Polymers	(3)
26-506	Polymer Structure, Properties, and Applications	(3)
26-509	Plastics Processing Theory I	(3)
26-510	Plastics Processing Theory II	(3)

In addition, the student must take 84-515 (Chemical Literature (2 credits)) and must register for Polymer Seminar (97.602) each semester.

The remaining formal course credits may be chosen from the graduate courses offered in polymer science and plastics engineering, with permission of the Dissertation Committee.

Candidacy for the Doctorate in Chemistry
To be admitted to candidacy for the doctorate, a student must

1. complete the first year's core of recommended subjects and have a satisfactory record in undergraduate training, graduate seminar and collateral reading.
2. complete the course credit requirements.
3. pass the area examinations.
4. fulfill the language requirements.
5. secure the approval of his/her advisory committee and the graduate coordinator of the Department of Chemistry.

When these requirements have been fulfilled, the graduate coordinator of the Department of Chemistry notifies the Dean of the Graduate School in writing and recommends that the student be placed on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

26-502 New Plastics Processing Techniques* *Schott* **(3-0)3**
Critical examination of new plastics processing techniques appearing in the research literature and being commercialized in the plastics industry.

26-503 Mechanical Behavior of Polymers *Crugnola* **(3-0)3**
Mechanical properties of bulk polymers as a class of engineering materials. The relation between the chemical/physical structure of polymers and their utilization as plastics, fibers and elastomers. The effect of molecular weight, molecular weight distribution, branching, cross-linking, order and crystallinity on bulk properties. Linear visco-elasticity and its application to creep, relaxation, dynamic and stress/strain response phenomena. The principles and the formulation of time/temperature superposition. The thermodynamic and statistical mechanics view of rubber elasticity. The failure behavior of polymeric materials and its interpretation on the molecular level.

26-504 Processing, Morphology, and Properties *Crugnola* **(3-0)3**
Effect of processing conditions on polymer fine structure and morphology, and the attendant changes in mechanical and physical properties. Theoretical interpretation of the interrelationships involved.

26-506 Polymer Structure, Properties, and Applications *Deanin* **(3-0)3**
The fundamental relationships between molecular structures, properties, and end-use applications of plastics materials will be explored in detail. Molecular structural features include chemical composition, molecular size and flexibility, intermolecular order and bonding, and supermolecular structure. Properties include processability; mechanical, acoustic, thermal, electrical, optical, and chemical properties; price and balance of properties. Applications include rigid solids, flexible solids, foams, films, and non-plastics applications.

26-507 Plastics Industry Organization *Deanin* **(3-0)3**
Economics of producing plastic raw materials and converting them into end products, from research and development to plant construction, and marketing. Market analysis of plastics production, processing, and consumer patterns; commercial development, sales, and technical service. Organization of the plastics industry for research and development, specialty and commodity production, profit, and growth.

26-509, 510 Plastic Processing Theory *Schott, Tayebi* **(3-0)(3-0)6**
Principles of heat transfer, rheology, mixing, crystallization, and chemical reactions involved in the processing of plastics, and their applications to plastics process engineering.

26-511 Multiphase Polymer Systems* *Deanin* **(3-0)3**
Compatibility of polymer blends, block and graft copolymers. Morphology of semicompatible systems, and theoretical relationships between structure and properties. Practical systems in development and production.

26-512 Plastics Foams* *Deanin* **(3-0)3**
Preparation, structure, and properties of plastics foams. Practical systems in development and production. Properties, applications, and markets for plastics foams and products made from them.

*These courses are given only when there is sufficient demand.

26-513 New Plastics Materials* *Deanin* **(3-0)3**
Critical examination of the new plastics appearing in the research literature and being field-tested for commercialization in the plastics industry.

26-515 Theory and Technology of Fiber Spinning *Schott, Tayebi* **(3-0)3**
Principles and theory of rheology, heat and mass transfer associated with the forming operations in melt and solution spinning of fibers. The equations of motion, continuity and energy are used to formulate the analytical description of fiber spinning. Applications of the theory are discussed in terms of equipment and practices of the synthetic fiber industry.

26-516 Composite Materials *Petrie* **(3-0)3**
The potential of composites as a class of materials, and the uniqueness of the mechanical/physical properties realizable. Fundamental concepts underlying those properties, with particular emphasis on fibrous reinforced plastics. Survey of matrices, reinforcements, and prediction of composite properties from a knowledge of properties and topology of constituent materials. Factors affecting ultimate strength and fatigue behavior.

26-518 Product Design *Deanin* **(3-0)3**
Theoretical principles and sound engineering practice involved in the design of new end products made from polymers, applying the total systems approach to the balance between product design, choice of materials, and process technique, as they affect competitive choice for commercial success.

26-519 Polymer Characterization* *Staff* **(3-0)3**
Survey of the leading physico-chemical techniques for characterizing the composition, structure, and morphology of polymer molecules and polymer systems.

26-521 Polymerization Engineering* *Deanin, Schott* **(3-0)3**
Engineering design of equipment and plants for polymer production. Processes for production of each of the major commercial polymers.

26-523 Material and Energy Balances in Plastics Processing *Schott* **(3-0)3**
Batch and continuous processes. Dimensional analysis. Thermodynamic properties of thermoplastics. The use of enthalpy diagrams in energy balances. Heat capacity, sensible heat, heat of fusion, and heat of reaction. Intensive and extensive properties of plastics. Phase changes and transitions in thermoplastics.

26-524 Process Analysis, Instrumentation, and Control* *Schott* **(3-0)3**
Industrial instruments for measurement and control of plastics processes. Design of experiments. Analysis of plastics forming operations. Dynamic testing techniques. Automatic plastics process control. Modeling and process simulation in extrusion and injection molding. Data acquisition systems.

26-525 Processing of Synthetic Fibers and Fiber Structures* *Pope/Arnold* **(2-2)3**
An introduction to systems utilized in the processing of synthetic fiber structures. These include drawing, winding, texturing, staple fiber production, blending, static control, dyeing and finishing. The effect of these mechanical, physical, and chemical processes on the resultant fiber and fiber structure behavior.

*These courses are given only when there is sufficient demand.

26-526 Advanced Processing of Synthetic Fibers and Fiber Structures* *Pope/Arnold* **(3-0)3**
A continuation of 26-525 to include a more detailed view of the processes and effects involved.

26-527 Mechanics of Fibrous Structures* *Tayebi* **(3-0)3**
Characteristics of fibers as affecting performance of conventional and non-conventional fibrous structures. Design considerations and mechanical behavior of twisted, knitted, woven, braided, and nonwoven fibrous materials.

26-528 Knitted and Non-Conventional Fiber Structures *Arnold/Pope* **(2-2)3**
Nonwoven materials and unusual fiber structures such as needle-punched, stitch bonded, and ultrasonic welded structures. Problems are assigned for laboratory evaluations and written reports as well as oral presentation are required.

26-529 Fiber Evaluation* *Pope/Arnold* **(2-2)3**
Basic mechanical tools, techniques and their utilization by industry for research, development, production control and end use evaluation. Moisture equilibrium and rates of change relations, basic fiber, yarn and structure dimensions; and an introduction to the determination and evaluation of the stress-strain-time properties of fibers and fiber structures; wear and abrasion are among the topics considered.

26-530 Introduction to Fiber Marketing, Management and Plant Organization* *Arnold/Pope* **(3-0)3**
An introduction to basic principles in the marketing, management, and plant organization of synthetic fibers. Consideration of distribution channels, costing, sales forecasting, management recruiting and machinery layouts.

26-531 Survey of Synthetic Fibers and Fiber Structures *Pope/Arnold* **(3-0)3**
General discussion of the basic problems encountered in the synthetic fiber industries, including fiber and fiber structure properties, processing, utilization and various aspects of current research. Recent advances and projected developments.

26-532 Adhesives and Adhesion* *Petrie* **(3-0)3**
Theories of Adhesion. Materials and compounding. Methods of application. Adherends and applications.

26-533, 534 Coatings Science and Technology* *Deanin* **(3-0)(3-0)6**
Polymers, pigments, solvents, and additives used in coatings. Methods of polymerization, formulation, application, and testing. Substrates and applications.

26-535 Rubber* *Deanin* **(3-0)3**
Polymerization and compounding of the commercial elastomers. Properties and test methods. Leading applications and methods of processing.

26-536 Rheology* *Schott/Tayebi* **(3-0)3**
Fundamental principles of the flow of polymers in bulk, melt, solution, and latex form. Flow instabilities associated with viscoelastic flow.

*These courses are given only when there is sufficient demand.

26-537 Engineering Properties of Plastics* *Petrie/Tayebi* **(3-0)3**
Theoretical basis and practical significance of the mechanical, thermal, electrical, optical, and chemical properties of plastic materials. Importance of engineering properties in material development and selection and in product design.

26-543, 544 Survey of Plastics Materials *Normandin* **(3-0)(3-0)6**
Not open to B.S. Plastics Students
Descriptive course centering on the historical development of polymeric systems, their synthesis, structure, properties, and applications. Included will be a brief discussion on the typical additives employed to make plastics molding compounds.

26-545 Methods of Experimental Analysis* *Thomas* **(3-0)3**
Methods of efficient design and analysis of scientific and industrial processing experiments. Classical vs. factorial experiments, statistical distributions and statistical inference, single and multifactorial analysis, interaction, correlation and regression.

26-583 Research Methodology* *Petrie* **(3-0)3**
A systematic evaluation of the techniques used in efficient research and development. Experimental data are analyzed and plotted using a mathematical approach. Creative thinking, problem solving and student presentation of data are stressed. Extensive reading of research papers, analysis of such and defense of the analysis is required.

26-601, 602 Plastics Seminar: Literature Searching *Staff* **(1-0)(1-0)2**
Survey of the technical literature in plastics, and techniques for searching it. Each student will carry out one literature research project per semester and report it to the class.

26-603, 604 Plastics Seminar: Current Journal Literature *Staff* **(1-0)(1-0)2**
Survey of the technical journals which carry reports of current advances in plastics science and engineering. Each student will report to the class on a portion of the current journal literature.

26-605, 606 Plastics Seminar: Research *Staff* **(1-0)(1-0)2**
Reports and discussions on current research in the department. Faculty and students will take turns presenting their current research activity, and turn to group discussion for guidance in solving their problems and planning their future work.

26-651, 652, 653, 654 Selected Topics in Plastics *Staff* **(3-0)(3-0)(3-0)(3-0)12**
Advanced topics in the various fields of plastics. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary plastics.

26-701, 702 Graduate Research in Plastics *Staff* **(0-9)(0-9)6**
Individual research projects in plastics chemistry, properties, processing, products, and industry organization.

26-751, 752, 753, 754 Advanced Projects in Plastics *Staff* **(0-3)(0-3)(0-3)(0-3)4**
Special projects undertaken by a student to expand his knowledge in specific fields not necessarily related to his thesis. Content of project and hours assigned must be approved by Department Chairperson.

*These courses are given only when there is sufficient demand.

COLLEGE OF HEALTH PROFESSIONS

Dean: Eleanor Forsley Shalhoup, *Associate Professor;* B.S., M.S., St. Anselm's College; C.A.G.S., Ed.D., Boston University.

Department of Nursing

Department Chairperson and Coordinator: May Futrell, *Professor;* B.S., M.A., Columbia University; Certificate, University of Southern California; Ph.D., Brandeis University.

Faculty

Donald Anderson *Instructor;* B.S., Boston University; M.S., University of Lowell.

Stephen Brovender, *Adjunct Associate Professor;* B.S., Brooklyn College; M.D., University of Brussels.

Veronica Charbonneau, *Instructor;* B.S., Union University; M.S., University of North Carolina.

Susan Houde, *Instructor;* B.S., Lowell State College; M.S., University of Lowell.

Elizabeth L. McKinnon-Mullett, *Professor;* B.S., Simmons College; M.Ed., Ph.D., Boston University.

William O'Rourke, *Adjunct Assistant Professor;* B.S., St. Bonaventure University; M.S., Holy Name College; M.Ed., University of New Hampshire; Ph.D., Boston College.

Janice Stecchi, *Associate Professor;* B.S., Boston College; M.Ed., Salem State College; M.S., Ed.D., Boston University.

Master of Science Degree Program

Philosophy of the Department of Nursing

The faculty of the Department of Nursing believes that Man is a unique rational being who has needs for safety and security, love and belonging, esteem and self-actualization, and who interacts purposefully in a changing environment. Man is perceived as a continually developing individual possessing innate rights and the ability to make choices and establish goals which determine his future. Fundamental to these rights is the right to attain optimal health. Nursing assists the individual to attain this level of health by facilitating adaptation that allows him to function at his developmental level within his social system.

Nursing, as a learned profession, is both an academic and a practice-oriented discipline. As an academic discipline, nursing is developing and refining its substantive and practical knowledge base through continuing scientific inquiry into its theory and its practice. Nursing science builds its body of knowledge through analysis of existing theories, leading to the syntheses of new conceptual relationships that can be operationalized in professional nursing practice. Nursing will have a strong role in determining health policy and practice in the future.

As members of a practice-oriented discipline, professional nurses interact in collaborative relationships with other health professionals to formulate a holistic approach when assisting individuals, groups, and communities to meet health needs. The cognitive, affective, and psychomotor competencies of the professional nurse are integrated and demonstrated in assessing, planning, implementing and evaluating direct and indirect care of clients. Practitioners of professional nursing accept the rights and responsibilities of self- direction for nursing judgements and decision-making in order to facilitiate the optimum well-being of their clients on the health illness continuum. Inherent in these professional responsibilities are the leadership skills of accountability, advocacy, delegation and supervision. As a service to man and society, nursing, through use of the nursing process, carries out professional nursing activities to assist the individual, the family, and the community in the pursuit of well-being.

The emerging role of the professional nurse will emphasize primary care and prevention in traditional and innovative health care settings to assist man in attaining his optimal level of health. This role is acknowledged as one which prepares the nurse to accept new responsibilities and to design and implement new approaches to delivery of health care.

The faculty believes that education is a self-actualizing, creative lifetime endeavor which involves values-clarification, progressive inquiry, critical analysis and judgement. Baccalaureate nursing education incorporates liberal education with generalized preparation in professional nursing. Support of the individual's growth and self-evaluation during the program enables the student develop his/her own professional philosophy which will be refined throughout his/her career.

The faculty believes that graduate level education in nursing focuses on specialization, research, and leadership preparation. Specialization includes both a clinical focus and a functional focus.

Advanced education is achieved through the synthesis of specialized knowledge, applied theory, and expanded skills.

Purpose

The purpose of the Master of Science in Nursing Program is to prepare nurse practitioners who promote health care in a variety of settings.

Admission Requirements

Baccalaureate degree with a major in Nursing from an accredited program.

An undergraduate scholastic average of B or better. Provisional acceptance may be considered if the candidate demonstrates graduate study potential by other means.

Introductory course in descriptive and inferential statistics.

Official scores on the Graduate Record Examination.

Photo copy of current licensure to practice nursing in the Commonwealth of Massachusetts.

Personal interview.

Three letters of recommendation pertaining to academic ability and professional competency.

Degree Requirements for the Primary Care Nurse Practitioner:

Credits

A minimum of 42 credit hours of course work will be required of all students enrolled in the program. There are no formal language requirements or comprehensive examination requirements. A project which will consist of a scholarly investigation or a thesis is required for graduation.

Degree Requirements for the Gerontological Nurse Practitioner for the 1981-1982 year

Credits

A minimum of 39 credit hours of course work will be required of all students enrolled in the program. Each student will complete three semesters within the calendar year. The third semester is a 12 week summer session of the University. There are no formal language requirements or comprehensive examination requirements. A project which will consist of a scholarly investigation or a thesis is required for graduation.

Beginning September, 1982, all candidates must meet the degree requirements for the Primary Care Nurse Practitioner as stated above.

Gerontological Nurse Practitioner Program

Expected Outcomes

Each student upon completion of the program of study is expected to:

1. Communicate a philosophy of gerontological nursing through practice.
2. Possess a body of knowledge basic to the practice of gerontological nursing.
3. Synthesize knowledge from gerontology, the behavioral sciences and natural sciences for the purpose of developing concepts and constructs for gerontological nursing practice.
4. Evaluate and apply theories in the application of nursing process to the care of the aged and aging population.
5. Demonstrate expertise in the areas of history-taking, health assessment and health care management of well and sick elderly.
6. Assume a nursing leadership role that includes innovation, consultation, advocacy, accountability and responsibility for improvement of health services to the aged.
7. Utilize research methodology to advance the practice of gerontological nursing.
8. Propose alternative solutions to problems in the delivery of health care to the elderly as a result of investigatory studies.
9. Evaluate effectiveness of community services designed to meet the needs of the aged and aging population and use appropriate resources to initiate change.
10. Collaborate with consumers and other health disciplines in matters of health care and social policy legislation.
11. Assume responsibility for on-going personal and professional growth.

Statement of Roles

The role of the Gerontological Nurse Practitioner is an evolving one and the combination of setting, client needs and individual style will determine the particular constellation of role components emphasized by each practitioner. The G.N.P. is prepared to perform all the following roles:

1. Direct provider of health services.
2. Independent and interdependent practitioner.

3. Educator of clients, families, community and self.
4. Change Agent.
5. Consultant in gerontological nursing to community agencies, planning, councils, nursing homes, day and ambulatory centers.
6. Collaborator with other health professionals and community agencies.
7. Role model for families, health professionals and communities.

Program of Studies

		Credits
Semester I		
30-550	Biological Aspects and Pathophysiology of Aging	3
33-600	Theoretical foundations for Advanced Nursing Practice	3
33-610	Gerontological Nursing I	3
33-613	Practicum in Gerontological Nursing I	4
	Total	13
Semester II		
47-551	Psychosocial Aspects of Aging	3
33-611	Gerontological Nursing II	4
33-614	Practicum in Gerontological Nursing II	4
33-553	Research Design and Methodology	3
	Total	14
Semester III		
33-615	Research in Gerontological Nursing	3
33-612	Gerontological Nursing III	6
	Elective	3
	Total	12
Summary of Subject Area Concentrations:		
1.	Gerontological Nursing	24
2.	Research in Nursing	6
3.	Supporting Courses:	
	a. Biological Aspects of Aging	3
	b. Psychosocial Aspects of Aging	3
	c. Elective	3
	Total	39

Courses of Study

30-550 Biomedical Aspects and Pathophysiology of Aging (3-0)3
Study of the biological aging process and its effect on the various physiological parameters of wellness in the older adult. Systems theory, as it

applies to Man, serves to unify conceptual approaches used to examine the physiological steady state and the disruptions that result in pathophysiological mechanisms and manifestations of disease states. The physiologic resources of the older adult in terms of defensive, compensatory, and adaptive responses to pathophysiologic processes are examined.

33-600 Theoretical Foundations for Advanced Nursing Practice **(3-0)3**

Examination of the development and formulation of nursing theory through systematic exploration of concepts and the process of theory building. The student will analyze and evaluate nursing theory from the viewpoint of new knowledge. Congruency between signficant nursing theories and nursing practice will be identified.

33-610 Gerontological Nursing I **(3-0)3**

Focus will be on a wide range of theories essential to understanding the needs of the aging population. Theories related to the following areas of concern will be examined: health care, change, economics, law, politics, and role. Particular attention will be paid to the relationship of these areas of concern to the well-being of the aged individual. The student explores in depth the organization and practices of health care delivery systems available to the elderly in a selected community. Strategies needed by the nursing practitioner to assist the elderly in achieving their optimum level of wellness will be analyzed.

33-613 Practicum in Gerontological Nursing I **(0-8)4**

The practicum is individualized. It takes into consideration prior experience of the student. It is a planned, continuous experience in health assessment, including history-taking, physical examination and psychosocial evaluation. The first seven weeks of the course are spent in the University Learning Lab, where didactic sessions on health assessment are held and students practice techniques of health assessment on their peers. The second half of the semester the students assess the health status of clients in ambulatory care clinics, a nursing home and day care center utilizing a problem oriented format. In this experience, students will practice according to their philosophy of nursing and in accordance with an identified conceptual system of nursing.

47-551 Psychosocial Aspects of Aging **(3-0)3**

Analysis of current social gerontological literature on theory and research pertaining to biological, psychological and sociological variables over the adult life span. Age changes in a situational context will be examined and discussed. Role change, health concerns in later life, special concerns such as racism, alcoholism, sexuality, retirement, finances, recreation and leisure will be studied. The course will cover the changes in behavior that occur from adulthood to old age with emphasis on changes in personality, mental health, sensation and perception, intelligence and learning; and those variables which contribute to successful aging. Common emotional problems such as loss, grief, and dying will be discussed. The most common functional disorders of old age will be studied. Particular attention will be given to organic brain syndrome, its assessment and its social consequences.

33-611 Gerontological Nursing II **(4-0)4**

This course builds on knowledge and theories identified in the previous semester. It strengthens the student's ability to make clinical decisions by

further defining responsibilities for nursing diagnosis and management in solving common health problems of the aging population. Theories of rehabilitiation, both physical and psychosocial are emphasized in the care of the elderly client. All of the above lead to independent and interdependent decision making which enables the student to demonstrate the role responsibilities and leadership functions of the Gerontological Nurse Practitioner. Through the utilization of case studies, the student proposes alternative solutions to problems in the delivery of health care to the elderly.

33-614 Practicum in Gerontological Nursing II (0-8)4
Building on the knowledge and experience achieved in the previous semester, the student develops expertise in assesssment and management of health problems of the elderly. Through the application of theory to practice under the supervision of nursing faculty, the student further defines his/her functions and limitations in the role of a gerontological nurse practitioner. Emphasis is placed on decision-making, leadership and role theory in the nursing management of physical and psychosocial problems of the elderly. Current research provides a reference base for developing plans of management.

33-553 Research Design and Methodology (3-0)3
Study and application of appropriate research methodologies in the investigation of a particular nursing problem concerned with the aged population. Included is an analysis of the relationship of the research process to nursing knowledge and practice, an overview of measurement and design problems and techniques of theory construction.

33-612 Gerontological Nursing III (2-16)6
The course focus is on the functional role of the nurse practitioner in primary care settings. A critical examination of role theory and behaviors expected of leaders in nursing is undertaken. Opportunities are provided for students to synthesize nursing, role and change theories in their practice and in practice setting. The leadership and collaborative aspects of the practitioner role will be emphasized.

33-615 Research in Gerontological Nursing 3 credits/Independent Study
Advanced study of research principles and practice, designed to assist the student in the completion of a master's project under the guidance and supervision of the faculty. The master's project is a scholarly paper that demonstrates an ability to review literature on a particular topic, to analyze and examine the readings for the purpose of extrapolating pertinent material and to synthesize this material for utilization and application in gerontological nursing.

Primary Care Nurse Practitioner Program

Expected Outcomes:

Each student upon completion of either the Family Nurse Practitioner or Adult Nurse Practitioner Track will be expected to:

1. Communicate a philosophy of primary care nursing through practice.

2. Possess a body of knowledge basic to the practice of either family or adult primary care nursing.
3. Synthesize knowledge from either family or adult primary care nursing, and the behavioral and natural sciences for the primary care nursing practice.
4. Evaluate and apply theories in the application of nursing process to the primary care of either the family and its members, or to young, middle, and aged adults.
5. Demonstrate expertise in the areas of history-taking, health assessment and health care management of well and sick clients.
6. Assume a nursing leadership role that includes innovation, consultation, advocacy, accountability and responsibility for improvement of health services to the client.
7. Utilize research methodology to advance the practice of primary care nursing.
8. Propose alternative solutions to problems in the delivery of health care to the client as a result of investigatory studies.
9. Evaluate effectiveness of community services, designed to meet the needs of the client and use appropriate resources to initiate change.
10. Collaborate with consumers and other health disciplines in matters of health care and social policy legislation.
11. Assume responsibility for on-going personal and professional growth.

Primary Care Nurse Practitioner Program

Family and Adult Nurse Practitioner Tracks
Program of Studies

Semester I

33-600	Theoretical Foundations for Advanced Nursing Practice	3
30-560	Concepts of Human Pathophysiology	3
33-651	Primary Health Care and the role of the Nurse Practitioner	3
33-650	Concepts and Skills in Health Assessment	3
	Total	12

Family Nurse Practitioner

Semester II:

33-660	Family Health I	4
33-663	Family Health I Practicum	3
33-556	Research Design & Methodology	3
	Total	10

Semester III:

33-661	Family Health II	4
33-664	Family Health II Practicum	3
47-561	Family Dynamics	3
	Total	10

Semester IV:

33-662	Family Health III	4
33-616	Nursing Research	3
Elective		3
	Total	10

Adult Nurse Practitioner

Semester II:

33-670	Adult Health I	4
33-673	Health I Practicum	3
33-556	Research Design & Methodology	3
	Total	10

Semester III:

33-671	Adult Health II	4
33-674	Adult Health II Practicum	3
47-561	Family Dynamics	3
	Total	10

Semester IV:

33-672	Adult Health III	4
33-616	Nursing Research	3
Elective		3
	Total	10

Summary of Subject Area Concentration

1.	Nursing Theory	6
2.	Nursing Specialty	21
3.	Nursing Research	6
4.	Supporting Courses	9
	a. Biological	
	b. Psychosocial	
	c. Elective	
	Total	42

Courses of Study

33-600 Theoretical Foundations for Advanced Nursing Practice (3-0)3
Examination of the development and formulation of nursing theory through systematic exploration of concepts and the process of theory building. The student will analyze and evaluate nursing theory from the viewpoint of clinical application and the development of new knowledge.

Congruency between significant nursing theories and nursing practice will be identified.

30-560 Concepts of Human Pathophysiology (3-0)3
Systems theory, as it applies to Man, serves to unify conceptual approaches used to examine the physiological steady state and the disruptions that result in pathophysiologic mechanisms and manifestations of disease states. The physiologic resources of individuals throughout the life cycle in terms of defensive, compensatory, and adaptive responses to pathophysiologic process are examined.

33-651 Primary Health Care and the Role of the Nurse Practitioner (3-0)3
Primary health care services will be examined relative to their impact on health care. Examination and analysis of Role Theory and the role of the nurse practitioner in terms of the settings will be made. Sociologic, economic, and environmental factors that influence the process of defining, negotiating, and implementing the nurse practitioner role are studied.

33-650 Concepts and Skills in Health Assessment (0-6)3
Concurrent with didactic sessions is a planned, individualized, continuous laboratory experience in health assessment. The experience includes data collection and recording through history taking, physical examination, and psychosocial evaluation. Didactic sessions on health assessment are held in the University learning laboratories where students practice techniques of assessment.

33-660 Family Health I (4-0)4
Study of the normal growth and development of the newborn, child, and young adult and the stresses which affect healthy growth and development. The health care needs of these clients and the skills and knowledges essential to the role of the family nurse practitioner in meeting these needs are analyzed. Deviation from wellness and the role of the practitioner in the restoration of wellness are studied.

33-663 Family Health I: Practicum (0-12)3
Building on the health assessment knowledge and skills achieved in the previous semester, the student develops expertise in assessment and management of health and health problems related to the newborn, developing child, and young adult. Under supervision of faculty, the student further defines practitioner functions. Working with clients in primary health care settings, emphasis is placed on decision-making and leadership in the nursing management of health problems common to these clients.

33-556 Research Design and Methodology (3-0)3
Study of the research process and the application of appropriate designs and methodologies in the investigation of health care problems concerned with individuals, clients, and/or families. Included are critiques of nursing and other health care research reports and analysis of the relationship of the research process to nursing knowledge and practice. Opportunity is provided for development of a protocol for a clinical research proposal.

33-661 Family Health II (4-0)4
Examination and analysis of healthy human reproduction, the concerns of young parents, middle aged and older adults will be the focus of study. Prevention of illness promotion, maintenance and restoration of optimum wellness and on the coping resources and mechanisms of these

clients in response to the psychosocial and physical stresses of normal aging and/or chronic illness will be emphasized.

33-664 Family Health II: Practicum **(0-12)3**
Opportunities for assuming responsibilities for health and maintenance, and the assessment and management of common health problems of the young parent, middle aged, and older adult are provided in primary care settings. Through the application of theory to practice, under supervision of faculty, the student further defines, implements and evaluates the practitioner role.

47-561 Family Dynamics **(3-0)3**
Traditional and non-traditional family structure and dynamics, functional and dysfunctional, will be studied. Concepts underlying the care of families during health-related stress crisis are analyzed. Exploration of effects of stress and crisis on family units and the modalities of intervention are discussed.

33-662 Family Health III **(0-12)3**
Primary health care settings are utilized to allow the student to develop knowledge and skills essential for independent and collaborative intervention in family health care. Opportunities will be provided for the student to function as a family nurse practitioner in the promotion, maintenance and restoration of wellness. Under the supervision of faculty, the student develops expertise in assessment and management, leadership and advocacy.

33-616 Nursing Research **3 credits/Independent Study**
Application of research design and methodology culminating in the completion of a masters project under the guidance and supervision of the faculty. The masters project is a scholarly paper that demonstrates an ability to conduct research for the solution of a nursing problem.

33-670 Adult Health I **(4-0)4**
The focus of this course is on the promotion of high-level wellness through the maintenance of health, prevention of illness and restoration of wellness in the adult client. The leadership role of the primary care nurse practitioner in preventive and predictive health care in the young, middle-aged and older adult is emphasized. The concept of clinical decision making essential to the assessment, diagnosis and nursing management of common short-term health problems in the adult client is studied.

33-673 Adult Health I: Practicum **(0-12)3**
Under the supervision of nursing faculty and the student applies theory to practice in primary care settings including ambulatory care clinics, community agencies and nursing homes. The practicum allows students to apply health assessment skills in a clinical agency for the purpose of determining levels of wellness and identifying problems in adult clients. The implementation of the leadership role of the adult nurse practitioner in preventive, predictive and restorative primary health care is the emphasis of the practicum. Faculty provide guidance for students in developing clinical decision making skills and in planning, implementing and evaluating nursing care for adult clients with short-term health problems.

33-556 Research Design and Methodology **(3-0)3**
Study of the research process and the application of appropriate designs and methodologies in the investigation of health care problems concerned

with individuals, clients, and/or families. Included are critiques of nursing and other health care research reports and analysis of the relationship of the research process to nursing knowledge and practice. Opportunity is provided for development of a protocol for a clinical research proposal.

33-671 Adult Health II **(4-0)4**

This course builds on the knowledge and theories identified in the previous semesters. The focus of the course is on the maintenance and restoration of optimum wellness in the young, middle and older aged adult with long-term health problems. The psychosocial and physical stresses of the aging adult with long-term disability and the need for adequate coping mechanisms will be examined. The role of the nurse practitioner in primary health care of adult clients with multiple long-term problems will also be analyzed. Emphasis will be on the need for advocacy and nursing leadership in setting priorities of health care, collaborating with other professionals in managing long-term problems and involving client, family and community resources in planning holistic health care.

33-674 Adult Health II: Practicum **(0-12)3**

Under the supervision of nursing faculty the student applies theory to practice in primary care settings including ambulatory care clinics, community agencies and nursing homes. The focus of the practicum will be on the health assessment and nursing management of adult clients with single or multiple long-term health problems. Students will analyze the effect of the psychosocial and physical stress of long-term health problems on clients and families and will develop and implement plans of nursing management for the purpose of strengthening coping mechanisms. Faculty provide guidance for students in further refining clinical decision making skills and in planning, implementing and evaluating nursing care for adult clients with long-term health problems.

47-561 Family Dynamics **(4-0)4**

Traditional and non-traditional family structure and dynamics, functional and dysfunctional, will be studied. Concepts underlying the care of families during health related crisis are analyzed. Exploration of effects of stress and crisis on family units and the modalities of intervention are discussed.

33-672 Adult Health III **(1-12)4**

This course is assigned to provide the student with an intensive clinical experience enabling her/him to strengthen health assessment and nursing management skills introduced in previous semesters. The student refines and demonstrates to others the independent, collaborative, leadership and advocacy aspects of the nurse practitioner role. Students synthesize nursing, role change and leadership theories in clinical practice for the purpose of assisting clients in attaining and maintaining their optimum level of wellness. A critical analysis of the leadership role of the nurse practitioner in proposing alternative solutions to health care delivery problems and in confronting role issues will be a component of the course.

33-616 Nursing Research **3 credits/Independent Study**

Application of research design and methodology culminating in the completion of a masters project under the guidance and supervision of the faculty. The masters project is a scholarly paper that demonstrates an ability to conduct research for the solution of a nursing problem.

COLLEGE OF LIBERAL ARTS

Dean: Patricia A. Goler, *Professor;* A.B., Regis College; A.M., Ph.D., Boston College; L.L.D. (Hon.) Regis College; D.H.L. (Hon.) Emmanuel College

DEPARTMENT OF PSYCHOLOGY

Department Chairperson: Allie Scruggs, *Professor;* B.S., Ed.M., Ed.D., Boston University

Graduate Coordinators: Anne Mulvey, *Assistant Professor;* B.A., Barat College; Ph.D., City University of New York. **Richard A. Siegel,** *Associate Professor;* A.B., Harvard College; M.S., Yale University; Ph.D., Boston University

Faculty

Jon C. Hellstedt, *Associate Professor;* A.B., Augustana College; B.D., Yale University; Ph.D., Boston University

David Landrigan, *Assistant Professor;* B.S., Tufts University; M.A., Ph.D., University of New Hampshire

Linda Silka, *Assistant Professor;* B.S., Oklahoma State University; M.A., Ph.D., Kansas University

Mary Roth Walsh, *Professor;* B.S., Mount Mary College; M.S., Cornell University; Ph.D., Boston University

Master of Arts in Community-Social Psychology

Philosophy and Objectives of the Program

A Master's level program in Community-Social Psychology is based on the philosophy that professionals trained at this level can make an important and needed contribution to the quality of community life. Through graduate study in the areas of community dynamics, social processes, and human interaction, with a firm grounding in research methodology, graduates of this program will be able to work in a variety of professional roles.

The field of Community-Social Psychology studies the relationship between social and environmental forces and the well-being of people. It seeks to understand the complex connections between the quality of life of individuals and related social factors, such as how economic recession or discrimination in education can cause depression, family tension, or social unrest. Community psychologists apply their skills to work toward social change in such areas as mental health, education, and family-community life. Such change can be achieved by working with institutions and agencies to better serve the community as well as with indi-

viduals and groups. The ultimate goal of community-social psychology is the prevention of human suffering by using strategies which extend beyond those of traditional mental health services to promote a greater responsiveness to the needs of individuals and groups by community agencies and institutions. Thus, while this program does provide advanced training in clinical and interpersonal skills, its major emphasis is on the preparation of professionals who will work primarily at the organizational level in administration, program development and evaluation, interagency coordination, and the like, rather than in direct one-to-one human service roles.

The Master's degree program in Community-Social Psychology at the University of Lowell is designed to help each student achieve the following objectives:

1. acquire a basic body of knowledge at the graduate level in the areas of community and social psychology and research methodology;
2. develop greater skill and sensitivity in the areas of interpersonal and intergroup relations;
3. achieve a better understanding of how environments and social-cultural forces affect people;
4. become more aware of the various individual, family and group problems that detract from the quality of personal and community life;
5. acquire the conceptual and research skills necessary for program development and evaluation;
6. develop the ability to apply psychological principles and skills to community problem-solving;
7. provide the opportunity to apply their learning in community settings in the Merrimack Valley and to gain skills and professional growth through direct experience and supervision in those settings.

Professional Roles

Community-social psychologists may apply their skills and learning in a variety of professional roles in various settings and at many levels. Typical and appropriate professional roles can include:

Consultant
Research/Program Evaluation
Program Planning and Development
Community Organization and Education
Administration and Coordination
Grant Writing and Funding

These professional roles can exist in many possible settings, including:

Community: Grass roots organizations, neighborhood groups, special interest groups, agencies, programs
Educational
Clinical/Medical/Public Health
Industrial
Mental Health/Human Service

These professional roles in these various settings can involve work at many possible levels, including the individual, small group, specific local agency or program, institutional, or governmental (city, state, or federal).

Admissions Requirements

The Community-Social Psychology program at the University of Lowell is designed both for recent college graduates as well as older and non-traditional students with experience in community settings. The requirements for admission include the following:

1. An undergraduate average of "B"or better in the field of psychology or a related major. Students from other major fields are invited to apply but may be asked to complete some undergraduate requirements. All applicants should have completed a basic statistics or research methods course, but students lacking this prerequisite may take the undergraduate course at the University.
2. Acceptable performance on the Graduate Record Examination Verbal and Quantitative Aptitude Section.
3. Three letters of recommendation related to the applicant's educational and professional qualifications.
4. A personal letter including a statement about the applicant's professional interests, educational and work qualifications, and future goals.
5. Prospective candidates may be requested to participate in an interview with members of the program's admissions committee.

Transfer Credit

Matriculated students in Community-Social Psychology are allowed to transfer up to 10 credits of coursework completed at other accredited universities, provided that such courses are within the content area of community-social psychology and that

they do not involve credit for field experience or professional work. Students with prior work experience in community settings may not receive transfer credit for such work but may request adjustments in specific program requirements.

Part-time Study and Non-Degree Status

While the program in Community-Social Psychology refers to full-time study, this is not the only form of graduate study; part-time students are encouraged to apply, with the understanding that they must nonetheless complete at least one semester of full-time study (8 credits or more) at the University of Lowell.

Students not pursuing an advanced degree or who wish to begin their graduate study without first applying for matriculated status are invited to register for selected specific graduate courses, contingent upon available spaces. Such students need meet only the first of the admissions requirements listed above. It should be understood that if a non-degree student later decides to apply for acceptance into the Master's program, his/her application will be treated equally along with all other new applicants, though performance in graduate courses taken at the University may be used as an additional admissions criterion. Non-degree students accepted as matriculated students may transfer a maximum of 12 credits earned at the University toward the Master's degree.

Graduate Adviser

Each newly-matriculated student in the program will be assigned to an individual graduate adviser from among the faculty of the graduate program. The student will meet with his/her adviser on a regular basis throughout the years of study to discuss course selections, planning for practicums, and the development of the thesis.

Degree Requirements

Credits

A total of 40 academic credits, at least 30 of which must be taken at the University of Lowell with a grade average of "B" or better and at least 8 of these taken during one semester of full-time study, is required for the Master's degree. These credits will be earned during two years of full-time study or part-time equivalent. Credits are earned through a combination of traditional classroom coursework, community field placements, and a Master's thesis.

Curriculum

The 40 credits necessary for the Master's degree are divided as follows:

Coursework		
Theory	9 credits	(incl. 47-501)
Community	10 credits	(incl. 47-520 and 525)
Methods	6 credits	(incl. 47-512 and 511 or 513)
Electives	6 credits	
Practicum	6 credits	
Thesis	3 credits	
	40	

A typical 2-year course of study will be as follows:

1st Semester		*Credits*
47-520	Introduction to Community Psychology	3
47-512	Advanced Research Methods	3
47-	Elective	3
2nd Semester		
47-525	Psychology of the Middle-Sized City	4
47-511	Counseling and Community Issues, or	
47-513	Communication in the Human Environment	3
47-	Elective	3
3rd Semester		
47-631	Practicum I	3
47-501	Human Development: Life Span	3
47-	Elective	3
47-	Elective	3
4th Semester		
47-632	Practicum II	3
47-741	Thesis	3
47-	Elective	3

Course Descriptions

Theory

47-501 Human Development: The Span of Life **(3-0)3**
Prerequisite: A recent course in some aspect of human development, or permission.
This course is designed to study the forces that influence stability and change in human development over the course of life. The life-span approach, based on chronological development, will be utilized with special emphasis given to topics particularly important at each age level. A major concern will be the interplay of biological factors, human interaction, social structures, and cultural forces in shaping the individual.

47-502 Contemporary Issues in Psychology **(3-0)3**
This course is designed to acquaint the student with new developments from a broad range of current psychological theory and research and with how these developments might affect social and community life. Topics for examination will vary but will include issues raised in diverse areas of psychology, such as learning and cognitive development, physiological psychology, personality and psychopathology, and forensic psychology.

47-504 The Family System **(3-0)3**
This course will focus on the psychological and interactional processes within the family, and the interplay between the family and other social, ethnic, religious, and socio-economic systems in the community. Topics examined will be the marital contract, parental roles, changing family structures, sibling influences, racial and ethnic factors, and the interaction between family and community life.

47-603 Human Development: Contemporary Issues **(3-0)3**
Prerequisite: 47-501
This course will involve exploration of research findings related to contemporary issues in human development. In-depth analysis of specific topics based on student interest will be an integral part of the course; for example, a comparison of cyclical versus lineal approaches to understanding human development.

47-604 Advanced Social Psychology **(3-0)3**
Prerequisite: A recent course in some aspect of social psychology, or permission.
The focus of this course will be on factors which develop when individuals affiliate and interact with one another in the community. Typical topics include conformity, ethnicity and its effect on social interaction, aggression and power, and gender identity and sex role behavior. Course content will include the process of attitude development and change, group development and functioning, and the influence of groups and individuals on one another.

Methods

47-511 Counseling and Community Issues **(3-0)3**
Theories of counseling and an analysis of techniques and approaches will be related to contemporary issues confronting those in the helping pro-

fessions. A major objective will be the development of a sensitivity to the problems and patterns of human behavior and an awareness of the institutions and agents that can use counseling to improve the quality of life. Representative issues might include: family conflict, drug and alcohol abuse, child abuse, wife abuse, depression and suicide, death and dying.

47-512 Advanced Research Methods **(3-0)3**

Prerequisite: Recent undergraduate course in Research Methods or Statistics that is satisfactory to the program faculty.

Methods of data collection including descriptive, correlation, experimental, explanatory studies, observation, surveys and studies using secondary sources, with attention paid to the ethical implications of research in psychology. The course will also focus on the analysis of data by computer, the meaning and interpretation of results, methods of reporting research, and the translation of results into pragmatic action. When appropriate, the content will emphasize research in community-social psychology.

47-513 Communication in the Human Environment **(3-0)3**

Prerequisite: Previous course work in social/organizational psychology or group dynamics, or permission.

The important factors in the processes of interpersonal and small group communication will be examined. The focus will be on how units of information, ideas and attitudes are transmitted between people and groups in the community. Students will have an opportunity to explore, experientially, the process of communication, to improve their own communication skills, and to develop techniques for improving the quality of human relationships.

47-611 Program Evaluation **(3-0)3**

Prerequisite: 47-512

Methods of program evaluation will be examined and implemented with particular emphasis on the differences between and compatibility of process and outcome evaluation. Special topics may include the politics of evaluation, the role of the evaluator, and the stages of evaluation from initial planning to utilization and implications of results. Relevant statistical and data analysis techniques will be discussed.

Community

47-520 Introduction to Community Psychology **(3-0)3**

A basic introduction to the field of community psychology, with an emphasis on the history, methods, and applications of the discipline. Topics covered may include: systems theory; impact of social structures and institutions on the quality of individual and community life; application of social intervention and social policy; relation to the community mental health movement; and an introduction to the local community and how it functions.

47-523 Women in the Community **(3-0)3**

The position and multiple roles of women will be examined in terms of women's contribution to the community, structural inequality, and options for social change in the interests of women as a group. Topics may include: women as advocates in securing community services for their families; as community leaders; as volunteers and paid workers; and as

recipients of social services. Social problems and related service or legislation affecting women may also be examined, including, for example, rape, battering and sexual harrassment, discrimination in employment practices, and inadequate child-care facilities.

47-524 Ethnic and Racial Factors in the Community (3-0)3
This course will be concerned with the multi-ethnic community and its effects on behavior, with major emphasis on conflict, prejudice, and accommodation. Additional topics to be considered may include: interpersonal skills and ethnic relations; personality and ethnicity; child-rearing and sub-cultural variations; and cognitive and language development.

47-525 Psychology of the Middle-Sized City: Lowell (3-3)4
An intensive study of Lowell, Massachusetts as a model for examining and understanding the social issues and complex systems of the middle-sized city. Factors influencing the quality of life of people residing in such settings will be examined from an interdisciplinary context which includes historical, economic, political, and cultural influences. A one-credit community project or placement is required in conjunction with this course.

47-621 Community Dynamics: Intervention and Change (3-0)3
Prerequisite: 47-520
The study and application of psychological principles to community intervention and social change, with an emphasis on understanding the systematic dynamics and other subtle aspects of the processes of intervention and change. This course will examine the structure and relationships of human resource systems (medical, educational, welfare, mental health) and will consider theories, strategies, and ethics of social change.

47-622 Selected Topics in Community-Social Psychology (3-0)3
Advanced topics in various areas of community-social psychology and related fields. Since topical coverage varies from year to year, a student may be allowed to receive credit for repeating this course. Specific seminar topics to be covered will be announced during preregistration, with particular prerequisites where appropriate.

Practicum

All matriculated students in Community-Social Psychology are required to engage in six credits of supervised field work in a community setting. Joint supervision will be provided through the initiative of program faculty in collaboration with community institutions and personnel. Three to four hours per week of field work over an academic semester are required for each credit earned. Credit will normally be earned through two three-credit experiences in a two-semester sequence during the second year of graduate study (i.e., after completion of 18 credits). Exceptions may be made to the timing and sequencing, but not the credit requirement.

47-631 Practicum I (1-9)3

47-632 Practicum II (1-9)3

Thesis

All matriculated students in Community-Social Psychology are required to complete a graduate thesis for the Master's degree. The thesis is a written report of original research or an original community project relevent to the field of community-social psychology. The standards and form for the thesis are those established by the Graduate School. A research-oriented thesis requires original analytical and/or experimental research designed and carried out by the student under faculty supervision. A project-oriented thesis requires the design, implementation and evaluation of a commuity-based project which is intended to have a positive and lasting impact on the community. In addition to the written thesis, the student will also prepare an oral presentation and defense of the thesis. Each thesis student will work under the supervision of a faculty member of the program, or, with approval of the student's Graduate Adviser, another faculty member in Psychology or other related fields. A maximum of 3 credits earned for thesis work may be counted toward the 40 credits required for the Master's degree, and thesis students must register for one or both of the following, in the same or consecutive semesters:

47-741 Graduate Thesis Seminar in Community-Social Psychology **(3-0)3**
Prerequisite: Completion of 18 credits of graduate work, and approval of Thesis Committee of the program.

For graduate students in the early stages of thesis planning, this seminar is designed to acquaint them with the mechanics and details of thesis work. Topics covered will include: literature searches, the development of a research hypothesis or project plan, methods of data collection and analysis or techniques of evaluation, standards of thesis writing, etc. The seminar will focus on the specific areas of thesis work of individual seminar students. The goal of the seminar is to help each student reach the stage of an acceptable written thesis proposal, although in unusual cases a student might be able to complete the thesis itself.

47-751 Graduate Research in Community-Social Psychology **3, 6 or 9**
Prerequisite: 47-741, or approval of Thesis Committee of the program

For graduate students actively engaged in research or project work leading toward the submission of a written thesis. A program of supervised study will be arranged between the student and a faculty supervisor. This course may be repeated for credit, but only a total of 3 credits from 47-741/751 may be counted toward the Master's degree.

COLLEGE OF MANAGEMENT SCIENCE

Dean: Daniel E. Diamond, *Professor;* A.B., University of Massachusetts, M.B.A., Boston University, Ph.D., New York University.

Graduate Coordinator: Santo J. Pullara, *Professor;* B.S., M.B.A., J.D., Ph.D., Syracuse University.

Faculty

William J. Burke, *Professor;* B.A., University of Massachusetts; M.Ed., Boston State College; J.D., Suffolk Law School.

Leslie M. Dawson, *Professor;* B.B.A., Iowa College; M.A., University of Toledo; Ph.D., Michigan State University.

George C. Dery, *Associate Professor;* A.B., Merrimack College; M.A., Boston College.

Charles T. Feeney, *Associate Professor;* B.S., Boston College; M.B.A., Northeastern University, C.P.A. (Massachusetts).

Brackston Hinchey, *Associate Professor;* A.B., M.A., Ph.D., College of Business & Public Administration, University of Missouri.

M. Riaz Khan, *Assistant Professor;* B.S., M.S., University of Karachi; M.A., M.B.A., Ph.D., State University of New York (Buffalo).

Linda H. Kistler, *Professor;* B.S., M.S., Colorado State University; C.P.A. (Massachusetts).

Goang-Tzer Liaw, *Associate Professor;* B.A., National Taiwan University; M.A., University of Minnesota; Ph.D., University of Illinois (Urbana).

Thŏmas C. Macbeth, *Professor;* A.B., Cornell University, M.A., Ph.D., University of Southern California.

Stuart L. Mandell, *Commonwealth Professor, Management;* B.A., Brooklyn College; M.B.A., Syracuse University.

Carol C. McDonough, *Professor;* B.A., Marymount Manhattan College; M.A., Ph.D., Boston College.

Yash Puri, *Assistant Professor;* B.Sc., M.Sc., M.B.A., Delhi University; M.B.A., D.B.A., Indiana University (Bloomington).

Hak K. Pyo, *Assistant Professor;* B.S., Seoul National University, Korea; Ph.D., Clark University.

Ralph A. Rieth, Jr., *Assistant Professor;* A.B., Dartmouth College; M.B.A., Ph.D., University of Massachusetts.

Joseph R. Rocha, Jr., *Associate Professor;* B.S., Northeastern University, M.B.A., New York University; J.D., Howard University, Ph.D., University of Iowa.

Ernesto Sanz, *Assistant Professor;* B.A., Loyola University, (Spain); M.A., Kamakura Language College (Japan); M.A., Sophia University (Japan): Ph.D., Boston College.

Irwin A. Shapiro, *Associate Professor;* B.S., Syracuse University, M.B.A., Indiana University, M.A., Ph.D., Clark University.

Balbir Sihag, *Assistant Professor;* B.A., Dayanand College, India; M.A. Punjab University India; Ph.D., Massachusetts Institute of Technology.

Paul E. Snoonian, *Associate Professor;* B.S., M.B.A., Northeastern University; M.A., Ph.D., Michigan State University.

Charles F. Thompson, *Assistant Professor;* B.S.A., Bentley College; M.B.A., Northeastern University; C.P.A. (Massachusetts).

Louis E. Yelle, *Associate Professor;* B.S., Lowell Technological Institute; M.S., M.B.A., Northeastern University.

James A. Zeitler, *Instructor;* B.A., Gannon College.

The Master of Business Administration (MBA) Degree Program

This program provides the student with access to first-rate graduate studies in business. Concentrations are available in areas of finance, marketing, operations, and general management. The award of an MBA degree signifies that the student has developed advanced skills in problem solving and decision making. The development of these skills in the University of Lowell program entails a searching examination of analytical tools, both theoretical and practical, and intensive training in their application through encounter with a wide range of topical cases. In addition, as part of their curriculum, students are required to undertake independent investigation and scholarly reporting, although the MBA is not primarily a research degree.

Entrance Requirements

Admission to the MBA program is open to students with the baccalaureate degree. An aptitude for management decision-making and a demonstrated academic ability are the most important qualifications for admission. It is also recommended that applicants have an adequate mathematics background. An exposure to calculus for business administration is highly desirable. Applicants should submit, along with their Graduate School application, a transcript of grades from their undergraduate institution, and a Graduate Management Admission Test (GMAT) score. Generally, to be eligible for admission a student should have attained an above-average GMAT score and a good grade point average.

Part-Time Student Status
We are aware that many interested applicants have full-time jobs and family responsibilities, and in an effort to ease their way, have provided for part-time student status. Part-time students may take five years to complete the program. There is also a provision for extension of this time limit, provided the student initiates application for it, and can show good cause.

Non-Degree Student Status and Admission to MBA Courses
Generally speaking, there is no provisional status - such as auditor or non-degree student - available in the MBA program. Applicants can be admitted only as fully-matriculated degree candidates. However, graduate students at the University of Lowell and other colleges in the area (with the permission of these colleges) may register for courses on an availability of space basis with the permission of the graduate coordinator. Under this provision, graduate students in other programs at the University are permitted to take courses in the MBA program if the courses can be used as electives to meet degree requirements in their program. Holders of the MBA degree may enroll in any course for credit. These students must have the necessary prerequisites for the course selected.

Residency Requirement
To be recommended for the MBA degree the student is required to complete successfully a minimum of twelve courses (36 credits) at the University of Lowell. Transfer students with graduate credits are required to complete a minimum of ten courses (30 credits).

Waiver of Courses
A student may waive without substitution up to four courses for having completed acceptable advanced undergraduate courses. Further, a student may waive two additional courses (6 credits) for courses taken in the MBA program at another graduate school, provided the courses and grades received are acceptable to the University of Lowell. Additional courses may be waived with substitution of acceptable courses.

After admission to the MBA program, students are expected to complete all courses at the University of Lowell, and only under special circumstances, and with prior approval, are students permitted to complete courses at other institutions.

Academic Grades, Probation and Suspension
Generally, the grading policy as stated in the Graduate School catalogue is followed. Students who earn in excess of six credit

hours with BC grades or lower will be placed on probation and subject to termination from the program. A student ordinarily is not allowed to repeat a course. Students who receive an F grade are automatically suspended from the program and may petition to the College's Graduate Administration Committee for reinstatement.

Curriculum Requirements

Forty-eight credit hours, sixteen courses, are required for the MBA degree. The following courses are required for all students.

60-601 Financial Accounting
64-601 Economics of the Firm
64-611 Quantitative Analysis
66-622 Marketing
66-632 Business Financial Analysis
66-651 Human Resources Management
66-672 Operations Management
66-673 Operations Research
60-612 Managerial Accounting
66-660 Business and Society
66-781 Business Policy
66-783 International Business

Four additional courses are required from a selected area of concentration.

Finance

66-731 Financial Management
66-732 Financial Markets and Institutions
66-739 Independent Study-Finance
Elective

Marketing

66-723 Market Analysis and Planning
66-724 Marketing Research
66-729 Independent Study-Marketing
Elective

Operations Management

66-772 Operations Planning and Control
66-774 Industrial Relations
66-779 Independent Study-Operations
Elective

General Management

66-789 Independent Study-Management
Three (3) Electives

Courses typically meet weekly from 5 p.m. to 7:30 p.m. and from 6 p.m. to 8:30 p.m. for fifteen weeks during the fall and spring semesters. During summer sessions, courses meet twice a week for fifteen meetings. A special registration schedule for MBA courses will be issued by the College of Management Science.

Students without computer science training must remove the deficiency. This may be done by taking 92-871 Digital Computer Programming.

Courses of Study

60-601 Financial Accounting **(3-0)3**
This course is designed to provide an understanding of financial statements which are provided to users, people and agencies, external to the economic enterprise. The course will include an examination of accounting procedures, financial accounting concepts, and the fundamentals of financial statement analysis and interpretation.

60-612 Managerial Accounting **(3-0)3**
Prerequisite: 60-601
This course is designed to provide an understanding of the uses of accounting information by internal management. Topics examined will include product costing systems, cost allocation methods, budgeting and forecasting techniques, and alternative decision tools and methods.

60-631 Federal Income Taxes **(3-0)3**
Prerequisite: 60-601
This course deals with the basic rules and regulations of the Internal Revenue Code as it affects individuals and business firms. Major emphasis will be placed on the role of taxation in the business decision-making process; for example, consideration will be given to the tax effects of alternatives as to the types of organization, depreciation and inventory methods, mergers and acquisitions and other important topics.

60-711 Theory of Financial Reporting **(3-0)3**
Prerequisite: 60-612
Study of the theory and rationale of corporate financial reporting with a study of the actual results found in current reporting practices of business firms. The aim of this course is to develop an insight into the strengths and weaknesses of financial reporting. Current trends in financial reporting will also be considered in light of their future impact.

64-601 Economics of the Firm **(3-0)3**
An analysis of how the market system operates. The examination of consumer behavior, production, and competition.

64-611 Quantitative Analysis **(3-0)3**
Introductory statistics and its role in business. Topics covered include variables and their distributions, sampling theory, hypothesis testing, simple and multiple regression, correlation, and decision theory.

66-622 Marketing **(3-0)3**
This course examines the process wherein the marketing strategies and plans of a competitive enterprise are formulated, implemented, and ad-

justed over time. Behavioral and quantitative aspects are covered, as well as analysis of the environmental forces affecting marketing decisions. The course is decision oriented and business cases are used extensively.

66-629 Independent Study in Marketing **(3-0)3**

66-632 Business Financial Analysis **(3-0)**
Prerequisite: 60-601
A study of financial principles and organization of business enterprise with emphasis on financial analysis, management of working capital, management of sources and cost of capital, and capital budgeting. Business cases, problems, readings, and reports.

66-651 Human Resources Management **(3-0)3**
This course examines the management of human resources in a wide variety of industrial settings. Case studies and readings are drawn from a cross-section of American industry and from firms of various sizes. The emphasis is behavioral and is concerned with recognizing, analyzing, and predicting certain internal and external forces affecting business operations. Communications, decision-making, leadership, discipline, and company hiring practices are covered.

66-672 Operations Management **(3-0)3**
Prerequisite: 64-611
A study of the techniques and models used in operations management. Topics include production design and process planning, layout of physical, facilities, production standards and work methods, job evaluation, forecasting and scheduling, inventory systems, quality control, and the use of simulation in manufacturing operations.

66-673 Operations Research **(3-0)3**
Prerequisite: 64-611
A study of operations research techniques useful in business and management decision-making. Topics include classical optimization, linear programming, dynamic programming, queuing theory, Markov chains, and simulation methods.

66-723 Marketing Analysis and Planning **(3-0)3**
Prerequisite: 66-622
Emphasizes managerial decision-making aspects of marketing, including design and use of models, marketing's organizational relationships, utilization of market research data, and performance evaluation and control through marketing audits.

66-724 Marketing Research **(3-0)3**
Prerequisite: 66-622
Examines the formulation, execution, and interpretation of marketing research projects, with Marketing Research being viewed within the broader context of a marketing intelligence system. Topics covered include research design, data collection methods, and sampling theory.

66-725 Marketing Communications **(3-0)3**
Prerequisite: 66-622
The social and economic role of promotion and the historical development of mass media and advertising. Advertising research, creation and production as a tool of marketing management. Other promotional tools examined via appropriate cases.

66-731 Financial Management (3-0)3
Prerequisite: 66-632
The purpose of this course is to develop skills of financial analysis for integrated managerial decisions. Emphasis will be on the optimum management of funds in a business organization and the techniques of financial analysis. Topics include valuation of the firm, capital budgeting, cost of capital, decisions under uncertainty, management of working capital, and other related topics. Readings and cases will be utilized.

66-732 Financial Markets and Institutions (3-0)3
Prerequisite: 66-632
Analysis of the theory and practice of financial intermediation by institutions in the financial markets.

66-736 Portfolio and Security and Analysis (3-0)3
Prerequisite: 66-632
Development of investment theory as applicable to portfolio management and securities selection. Readings and cases.

66-737 Seminar in Current Topics in Finance (3-0)3
Prerequisite: 66-632
Selected topics having current and future impact in the field of finance.

66-738 International Financial Management (3-0)3
Prerequisite: 66-632
This course presents the international dimension of the finance function of the firm. Financial constraints of the international environment and their effect on the standard concepts of financial management will be studied. Students will be exposed to the techniques of adapting risk analysis to the international situation. Study of international currency flows, monetary systems, forward cover and international banking policies will be included.

66-739 Independent Study in Finance (3-0)3

66-772 Operations Planning and Control (3-0)3
Prerequisite: 66-672
This course focuses upon the many complex decisions which an operations manager faces. Topics include the design of forecasting, production planning, inventory control, and quality control systems, and how each of these systems is integrated into the firm as a whole. Cases and readings will be used extensively.

66-773 Advanced Operations Research (3-0)
Prerequisite: 66-673
This course is intended to provide a thorough development of Dynamic Programming, Integer Programming and Combinatorial models, Stochastic Programming models, Probabilistic Inventory models, and Waiting Line models. The significance of the models, their potential problem-solving capabilities and limitations, including computational experience and applications, will be stressed.

66-774 Industrial Relations (3-0)3
A study of public policy toward labor-management relationships. The course focuses upon regulation by the National Labor Relations Board. Other topics include collective bargaining, arbitration, civil rights, and the application of anit-trust law to unions.

66-779 Independent Study in Operations Management **(3-0)3**

66-781 Business Policy **(3-0)3**

Prerequisites: 66-622, 66-632, 66-651, 66-672

This course emphasizes strategic long-range planning and organization to illustrate the interrelationship of the various functional areas of business. Case analysis is used extensively to bring out the practical aspects of the total management problems.

66-783 International Business **(3-0)3**

Prerequisites: 66-622, 66-632, 66-651, 66-672

The course is designed to develop management decision-making ability in international business. Problems and policies will be analyzed with attention to private versus government interests. The student is introduced to the functional areas of international business operations, particularly marketing and finance.

66-789 Independent Study in General Management **(3-0)3**

COLLEGE OF MUSIC

Dean: Thomas G. Elliot, *Associate Professor;* B.M., M.M., D.M.A., Boston University

Graduate Coordinator: John K. Ogasapian, *Professor;* B.M., M.M., Ph.D., Boston University

Faculty

Donald Bravo, *Professor;* B.M., New England Conservatory; M.M., Boston University.

Alma O. Espinosa, *Assistant Professor;* B.M., Eastman School of Music; M.M., Pius XII Institute; A.M., Ph.D., New York University.

Paul Gayzagian, *Professor;* B.M., M.M., Ed.D., Boston University.

Ingul Ivan Oak, *Assistant Professor;* B.M., M.M., New England Conservatory.

Natalo Paella, *Associate Professor;* B.M., Louisiana State University; M.M., New England Conservatory.

William Pordon, *Associate Professor;* B.M., M.M., Chicago Conservatory College.

Domenic R. Procopio, *Professor;* B.A., M.A., Harvard University; Ph.D., Boston University.

Kay George Roberts, *Assistant Professor;* B.A., Fisk University; M.M., M.M.A., Yale University.

David Sears, *Visiting Lecturer;* B.M., M.M. Peabody Institute; D.M.A., Boston University.

I. Stuart Smith, *Associate Professor;* A.B., Rutgers University; M.F.A., Brandeis University; Ed.D., University of Massachusetts.

Rawn W. Spearman, *Associate Professor;* B.S., Florida A. & M. University; M.A., Ed.D., Columbia University.

Willis Traphagan, *Professor;* B.M., Ithaca College; M.M., Boston University.

W. Anne Trenkamp, *Assistant Professor;* A.B., Mather College of Case Western Reserve University; M.M., University of Michigan; Ph.D., Case Western Reserve University.

J. Alan Whiston, *Associate Professor;* B.S., M.S., University of Akron.

Robert A. White, *Assistant Professor;* B.M., New England Conservatory; A.M., Harvard University.

The College of Music offers the degree *Master of Music* (M.M.) in the fields of Music Education, Music Theory/Composition, Musicology, Performance, and Performance/Conducting.

Admission Requirement

Applicants for admission to the Master of Music program must possess a bachelor's degree or the equivalent with a major in mu-

sic. Those holding degrees in other disciplines will be expected to take prerequisite undergraduate courses for no graduate credit to bring themselves to a level commensurate with that attained by an undergraduate music major. The prerequisites may be waived, at the discretion of the College, on the basis of distinguished placement examination results and audition performance.

All applicants are expected to present an undergraduate record of sufficient quality to assure a reasonable expectation of successful graduate work. Candidates for admission must submit the application forms of the Graduate School and the requisite form for application to graduate programs of the College of Music. All applicants must supply complete transcripts of their previous post-secondary work. These transcripts must be mailed directly from the institution at which the work was done.

In addition, applicants for admission into the Music Education program must supply scores of the Miller Analogies test, and the three letters of recommendation submitted to the Graduate School should be from persons in a position to evaluate both musical and professional capabilities. In addition, evidence of satisfactory student teaching and an essay as specified on the College of Music application form should be supplied.

Music Theory/Composition applicants must supply scores of the Graduate Record Advanced Test in Music, a portfolio of compositions equivalent to that required of undergraduate majors as specified in the College of Music's undergraduate bulletin, and at least one letter of recommendation from a major professor in the candidate's previous institution in a position to assess the quality of previous work and potential for future development.

Musicology applicants must submit scores of the Graduate Record Advanced Test in Music, a sample of expository writing showing research technique (e.g., a copy of an undergraduate thesis or term paper), and at least one letter of recommendation from a major professor at their previous institution in a position to assess the quality of their scholarship and potential for significant scholarly contribution to music.

Performance applicants will be expected to demonstrate a high degree of achievement in their chosen performance medium as a part of the audition procedure. Special auditions are arranged for *Performance* applicants. In the case of *Performance/Conducting* applicants, each applicant will be auditioned in both conducting and his/her major performance medium. *Performance/Conducting* applicants should also present evidence of undergraduate work in the following areas: conducting, instrumentation and/or orchestra-

tion, and studies in several fields of musical performance representative of the various families, i.e., strings, woodwinds, brass, percussion and voice. Further information may be obtained from the Chairman of the Department of Performance.

Upon receipt of all documents and completed application forms, the candidate will be evaluated by the Graduate Committee of the College of Music. All candidates who meet the academic standards of the College will be invited to audition. Applicants at too great a distance may submit a tape directly to the chairman of the Department of Performance of the College of Music, but will be expected to audition in person at the time of their placement examination at the beginning of their initial semester of matriculation.

Successful candidates for admission will be given placement examinations in music theory and history prior to their initial registration. Any deficiencies in either or both areas must be made up by taking undergraduate prerequisites for no graduate credit prior to being admitted to graduate level courses in the areas of deficiency.

Each graduate student will be assigned an adviser with whom he/she will work out a plan of study consistent with the curricula of his/her major and any deficiencies, as noted above.

Credit Requirements

The curricula for the Master of Music degree have in common the general configuration of at least 33 credits, including courses, at least two semesters of Applied Music study on the major performance medium, and at least two semesters of satisfactory ensemble participation. In addition, all candidates for the M.M. degree must complete a satisfactory terminal project. In the case of Performance degree candidates, the terminal project is defined as two public recitals with accompanying written notes. Performance/Conducting candidates must present a public performance as conductor and a related analytical document.

In the case of Musicology and Music Education candidates, a thesis on a topic approved by, and under the supervision of, the appropriate faculty will be required. Music Theory/Composition candidates will determine the nature of their terminal project, whether composition or thesis, in consultation with the faculty of their area.

Specific programs are tailored to each student's area of competence and interest by the student and his/her adviser, subject to the approval of the faculty. All students must take 74-596, Introduction to Graduate Study.

Musicology and Music Education candidates must take a minimum of 3 credits (one course) in the area of music theory. Music Theory/Composition and Music Education candidates must take a minimum of 3 credits (one course) in the area of music history, in addition to Introduction to Graduate Study. Music Education candidates should elect a minimum of 15 credits (five courses) in their area of concentration, of which no more than 3 credits (one course) may be satisfied through a workshop. Musicology and Music Theory/Composition concentrators should elect a minimum of 15 credits (five courses) in their specific area of concentration.

Performance candidates must take 16 credits of specified applied music, 8 credits of ensemble (usually four major ensembles where applicable), and 9 credits (three courses) of music electives exclusive of ensembles. *Performance/Conducting* candidates must take 12 credits of specified literature and techniques seminars, 6 credits of conducting practicum and seminar, 4 credits of specified applied music, 2 credits of ensembles and 9 credits of music electives, exclusive of ensembles.

Language Requirements

Musicology candidates must demonstrate knowledge of German sufficient to read scholarly literature of their field in that language with adequate comprehension. Music Theory/Composition majors must demonstrate a similar level of reading comprehension in either German or French. Language requirements must be satisfied prior to taking the Comprehensive Examinations.

Comprehensive Examinations

All candidates must pass Comprehensive Examinations demonstrating their understanding of basic historical and theoretical concepts in the field of music, as well as an in-depth examination in their major field of concentration. Every assistance is offered the candidate by the faculty of the College of Music to insure, insofar as is possible, his or her success in passing the Comprehensives with distinction. The candidate should discuss proper preparation for the comprehensives with his or her adviser.

Transfer Credits

No more than 10 credits may be transferred from any other institution into the Master of Music program. Non-degree students taking courses at the University of Lowell may transfer no more than 12 combined credits earned at this University and at any

institution prior to matriculation. No credits will be transferred from other than an institution accredited to grant graduate degrees in music toward any requirements in music courses at this institution. All transferred music credits are subject to validation by equivalency examination in the College of Music prior to being accepted and entered on the candidate's transcript.

Music Theory and History

Course Offerings

71-500 Theory Review *Sears* **(3-0)3**
A review of common-practice part writing and analysis. Credits cannot be counted toward the M.M. requirements.

71-501 Analytical Techniques I *Faculty* **(3-0)3**
Formal, contrapuntal and harmonic analysis of common practice repertoire.

71-503 Theoretical Concepts *Trenkamp* **(3-0)3**
A study of major concepts in music theory in preparation for the Comprehensive Examination in Theory.

71-526 Analysis of Contemporary Music *Trenkamp* **(3-0)3**
Formal, contrapuntal and harmonic analysis of twentieth century repertoire, both serial and non-serial.

71-601 Topics in Common Practice Analysis *Faculty* **(3-0)3**

71-626 Topics in Contemporary Musical Analysis *Faculty* **(3-0)3**

71-795 Directed Study in Composition (Thesis) *Faculty* **(3-0)3**

71-796 Directed Study in Music Theory (Thesis) *Faculty* **(3-0)3**

74-503 Historical Concepts *Ogasapian* **(3-0)3**
A study of major concepts in music history in preparation for the Comprehensive Examination in Music History.

74-539 Eighteenth and Nineteenth Century American Music *Ogasapian* **(3-0)3**
Examination of various aspects of American art music during its formative decades.

74-548 J. S. Bach *Ogasapian* **(3-0)3**
Representative music of the composer. Emphasis on the stylistic traits and latest research reordering the chronology of Bach's work.

74-549 Mozart *Espinosa* **(3-0)3**
An in-depth study of the development of Mozart's compositional style through an examination of representative works.

74-564 History of Music Theory *Ogasapian* **(3-0)3**
The main currents of musical notation theory and philosophy from the classical and patristic philosophers to the present are surveyed.

74-596 Introduction to Graduate Study in Music *Espinosa* **(3-0)3**
Research techniques, bibliography, form and style in the preparation of formal scholarly papers in music.

74-597 Oratorio and Cantata *Faculty* **(3-0)3**
The evolution of major choral forms in music history.

74-661	**Seminar in Medieval Music**	*Ogasapian*	**(3-0)3**
74-662	**Seminar in Renaissance Music**	*White*	**(3-0)3**
74-663	**Seminar in Baroque Music**	*Espinosa*	**(3-0)3**
74-664	**Seminar in Music of the Classic Period**	*Espinosa*	**(3-0)3**
74-665	**Seminar in Romantic Music**	*Ogasapian*	**(3-0)3**
74-666	**Seminar in Twentieth Century Music**	*White*	**(3-0)3**
74-667	**Musicology Seminar: Topics in the History and Literature of Music**	*Faculty*	**(3-0)3**
74-696	**Directed Study in Musicology**	*Faculty*	**(3-0)3**
74-796	**Directed Study (Thesis) in Musicology**	*Faculty*	**(3-0)3**

Performance

Course Offerings

72-510	**Vocal Ensemble**	**(0-2)1**
72-520	**Instrumental Ensemble**	**(0-2)1**
72-610	**Vocal Ensemble**	**(0-4)2**
72-620	**Instrumental Ensemble**	**(0-4)2**

(Graduate students may fulfill the ensemble participation requirement through membership in such performing organizations as the Symphony Orchestra, Wind Orchestra, Concert Choir, Opera Studio, etc., or, with special permission, by regular participation in smaller, more specialized chamber ensembles).

72-501, 502	**Applied Keyboard IX, X**	**(1/2-10)2**
72-511, 512	**Applied Voice IX, X**	**(1/2-10)2**
72-521, 522	**Applied Woodwinds IX, X**	**(1/2-10)2**
72-531, 532	**Applied Brass & Percussion IX, X**	**(1/2-10)2**
72-541, 542	**Applied Strings IX, X**	**(1/2-10)2**
72-551, 552	**Performance Keyboard VII, VIII**	**(1-20)4**
72-561, 562	**Performance Voice VII, VIII**	**(1-20)4**
72-571, 572	**Performance Woodwinds VII, VIII**	**(1-20)4**
72-581, 582	**Performance Brass & Percussion VII, VIII**	**(1-20)4**
72-591, 592	**Performance Strings VII, VIII**	**(1-20)4**
72-651, 652	**Performance Keyboard IX, X**	**(1-20)4**
72-661, 662	**Performance Voice IX, X**	**(1-20)4**
72-671, 672	**Performance Woodwinds IX, X**	**(1-20)4**
72-681, 682	**Performance Brass & Percussion IX, X**	**(1-20)4**
72-691, 692	**Performance Strings IX, X**	**(1-20)4**

75-550 Instrumental Techniques *Faculty* **(3-0)3**
Approaches the techniques and methods used by the instrumental conductor in solving problems of ensemble balance, blend, intonation, tone quality, rhythmic clarity, phrasing, vibrato and artistic interpretation. The

historical evolution of the conducting technique, related performance practices, programming and staging will also be an integral part of the course.

75-552 Choral Techniques *Faculty* **(3-0)3**
A practical course designed to furnish information on a wide range of topics related to choral conducting techniques and methods. Includes voice classification, quality, production, range, anatomy and physiology and the integration of the individual voice into the ensemble. The problems of securing artistic performance, intonation, balance, blend, vibrato and technical facility will be stressed. The historical evolution of the conducting technique, related performance practices, programming and staging will also be an integral part of the course.

75-595 Directed Study and Research in Performance *Faculty* **(3-0)3**

75-650 Conducting Practicum & Seminar I *Faculty* **(3-0)3**
A detailed and partly independent study of both advanced baton techniques and those techniques used in score analysis, preparation and rehearsal, extending the materials and skills developed in the Literature and Techniques courses through practical application, under guidance, in conjunction with one or more instrumental experiences.

75-652 Conducting Practicum & Seminar II *Faculty* **(3-0)3**
A continuation of 75-650 to a more advanced level, culminating in the presentation of a document and a public performance.

75-654 Seminar in Instrumental Literature *Faculty* **(3-0)3**
A study of stylistic elements, orchestration, formal structure, problem analysis and historical perspective in a selection of major (standard) works from the symphonic band and orchestra repertoire. The course will also deal with available sources (publishers) and catalogue listings for the various media. Regular listening and reading assignments and independent research will be included.

75-656 Seminar in Choral Literature *Faculty* **(3-0)3**
This course surveys the various approaches to the major genres and texts associated with the Requiem Mass, the Mass, Oratorio, Passion, Motet, Anthem, Te Deum, Magnificat, et al. The history and stylistic approaches in a unitized frame are observed and discussed through reports, performances, readings and recordings.

75-695 Directed Study and Research in Performance *Faculty* **(3-0)3**

75-696 Directed Study and Research in Performance *Faculty* **(3-0)3**

75-796 Directed Study and Research in Performance *Faculty* **(3-0)3**

Music Education

Credit Requirements

The M.M. in Music Education emphasizes broad preparation for advanced professional responsibilities through a program based upon extensive study in the field of music. The requirements are developed and administered by the Graduate Faculty of the Music Education Department, subject to the approval of the College of Music Graduate Committee.

It is an advanced professional degree designed to prepare students as music educators in elementary schools, secondary schools and colleges. Major emphasis is placed on scholarly research and practicum in the improvement of instruction and curriculum. The program for the degree also may be designed to satisfy Massachusetts certification requirements.

The curriculum is aimed at the preparation of music educators who will (1) have a comprehensive knowledge of the subject matter of music; (2) have an awareness of current theory and practice in music education; (3) be familiar with recent developments in general education, particulary in administration, supervision, curriculum, and research; and (4) demonstrate competence in developing, coordinating and supervising instruction programs in music.

Course Title	*Credits*
Introduction to Graduate Study	3
Applied Music	4
Ensemble(s)	2
Music Theory Elective	3
Music History Elective	3
Research in Music Education	3
Education Elective	3
Music Education Course Electives (to include a minimum of *four* courses	12
or	
Music Education Course Electives (*three*)	9
plus Music Education Workshop(s)	3
Directed Study (Thesis)	3
	36

All students in Music Education are urged to complete a minimum of one year full-time teaching in the public schools (or its equivalent) before initiating graduate study in *Music Education.*

Knowledge of foundations of music education methods, research methods problems and curriculum development in music education will ordinarily be obtained through successful completion of at least 18 credits in courses and workshops such as those listed in departmental offerings in the College of Music bulletin under course offerings.

In consultation with his/her adviser, the candidate may elect courses in music education or allied studies in accordance with his/her background and professional interests.

Course Offerings

73-566 Current Issues in Music Education *Gayzagian* **(3-0)3**
Examination and evaluation of current trends in music education and their philosophical basis, as well as their correlation and the development of a personal philosophy.

73-551 Research in Music Education *Faculty* **(3-0)3**
Methods of scientific inquiry in music education. The gathering, correlating, evaluating, and reporting of quantitative and qualitative data. Experimental design in music education.

73-564 Affective Learning through Music *Gayzagian* **(3-0)3**
The integration of the affective domain into the music education curriculum.

73-570 Administration and Supervision in Music Education *Gayzagian* **(3-0)3**
Contemporary concepts of supervision and administration, including philosophy, techniques, curriculum, budget, community and personal relationships, and staff evaluation.

73-575 Art Music of Black Americans *Spearman* **(3-0)3**
A survey and stylistic examination on the Black American musical experience.

73-580, 589 Workshops **(3-0)3**
Specific concentrated experiences in various facets of music education skills, including Orff-Kodaly (580, 581), beginning and advanced; Strings (582); Brass (583); Woodwinds (584); Marching Bands (585); Bands (596); Orchestra (587); Choral (588); Music Theater (389). Workshops generally are conducted during the summer in two-week, all-day sessions.

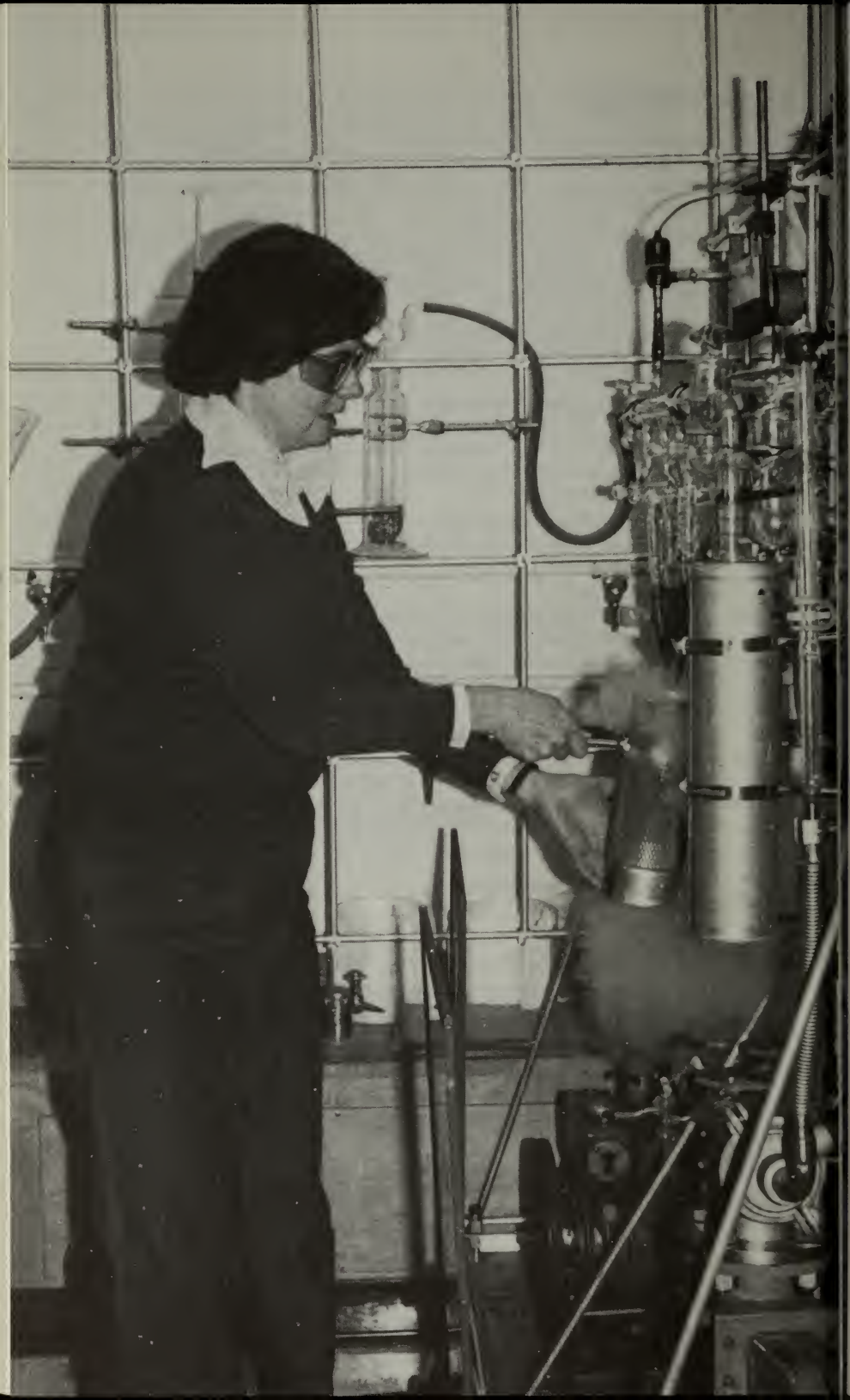
73-590, 599 Workshops: Special Areas **(3-0)3**
Specific concentrated experiences in specialized facets of music education, conducted by visiting or resident experts in the area. The areas are of an exceptional nature (e.g., Dalcroze Eurhythmics, Learning Disabled Child and Music), and are offered as announced.

73-601 Seminar in Music Education *Faculty* **(3-0)3**

73-602 Topics in Music Education *Faculty* **(3-0)3**
Non-seminar, non-terminal directed study.

73-670 Seminar in Administration and Supervision *Gayzagian* **(3-0)3**

73-796 Directed Study in Music Education (Thesis) *Faculty* **(3-0)3**



COLLEGE OF PURE AND APPLIED SCIENCE

Dean: Joseph Salamone, *Professor;* B.S., Hofstra University; Ph.D., Polytechnic Institute of Brooklyn.

Department of Biological Sciences

Department Chairperson: Thaddeus V. Osmolski, *Associate Professor;* B.S., University of Rhode Island; Ph.D., Brown University.

Graduate Coordinator: Nicholas J. Rencricca, *Professor;* B.S., St. Francis College; M.S., St. John's University; Ph.D., Boston College.

Faculty

John I. Bruce, *Professor;* B.S., Morgan State College; Ph.D., Howard University.

Robert M. Coleman, *Professor;* B.S., Bates College; M.S., University of New Hampshire; Ph.D., University of Notre Dame.

David T. Eberiel, *Assistant Professor;* B.S., Bethany College; M.S., Tufts University; Ph.D., Boston College.

Jerome L. Hojnacki, *Assistant Professor;* B.S., Southern Connecticut State College; M.S., University of Bridgeport; Ph.D., University of New Hampshire.

Ethel N. Kamien, *Professor and Associate Chairperson of Department;* B.A., Brooklyn College; M.S., Ph.D., University of Wisconsin.

Robert D. Lynch, *Associate Professor;* A.B., Northeastern University; M.S., D.Sc., Harvard School of Public Health.

John C. Mallett, *Associate Professor;* B.S., College of the Holy Cross; M.S., Ph.D., University of Rhode Island.

Ezequiel R. Rivera, *Associate Professor;* B.S., Sul Ross State College; M.S., Purdue University; Ph.D., University of Texas (Austin).

Ilze B. Skare, *Associate Professor;* B.A., University of Connecticut; Ph.D., Duke University.

Lee-Jun C. Wong, *Assistant Professor;* B.S., National Taiwan University; Ph.D., The Ohio State University.

Master of Science Degree Program

The Master of Science Program in Biological Sciences is designed to afford the student an opportunity for advanced study and train-

ing necessary to conduct independent research at a professional level. Students in the program will be encouraged to explore quantitative approaches to the solution of problems in the basic and applied biological sciences. Students have the option of selecting either an in-depth thesis program or an in-breadth course work program; in either case the student is expected to demonstrate that he has mastered sufficient knowledge and skills to pursue independent and creative research activities.

Entrance Requirements and Procedures
Entering graduate students are expected to have a sound preparation not only in the biological sciences, but also in chemistry, physics, calculus, and statistics. A student found deficient in any of these areas may be required, during the first year of residency, to take appropriate courses to eliminate the deficiencies. Every entering student is assigned a departmental adviser who will help him plan his first semester's program of study, acquaint him with research opportunities in the department, and assist him in selecting a thesis supervisor.

Degree Requirements
A minimum of 33 semester hours of graduate level work is required for the M.S. degree. Each student's program is formulated on the basis of his/her possible research interests, background, and professional goals in consultation with his/her adviser and Graduate Committee. The committee generally consists of the student's thesis adviser and at least two additional members, one of whom must be from the Department of Biological Sciences. There is no formal language requirement.

Thesis Option - the student concentrates on an in-depth independent investigation of a contemporary biological problem. Graduate credit is allowed for 9-12 semester hours of Graduate Research in Biology (81-701).

If selecting the thesis option, each student must select a committee and orally present to it a proposal of intended research. After completing the Master's thesis, the student must present a defense of his work in a seminar.

Non-Thesis Option - This program is available to all applicants with an undergraduate science degree and may be of special interest to secondary school science teachers and individuals employed in industrial and hospital laboratories who can attend late-afternoon-evening courses and enroll in six-week summer session courses. It is possible for students to complete this program in two academic years plus one summer.

Qualified individuals having an M.S. degree may apply some of the courses towards the Ph.D. Program in Chemistry (Biochemistry option) offered jointly by the departments of biology and chemistry or to promotion tracks beyond the Master's degree level. A minimum of 33 semester hours of graduate level work is also required for this option.

Professional Internship - (81-500) 3 credits

Credits will be given to qualified individuals who have participated in secondary school science teaching, hospital or industrial laboratory programs or related work efforts.

Core Requirements for all Options

Laboratory Instrumentation (81-530) 3 credits

A course designed to give students practical hands-on-experience with modern laboratory instrumentation and techniques. Many of these procedures will be of practical importance for those employed in laboratories and can also be adapted for use in high school science curricula.

Graduate Seminar in Biology (81-601, 602) 2 credits each

Students participating in two such two-credit courses will present reports on advanced topics, original research or journal articles.

Electives

Although the majority of the faculty members in the Department of Biological Sciences have a strong orientation toward biomedical research, several members have interests in the areas of ecology, plant anatomy/physiology and cell biology. In addition to the electives listed below, eight credits of graduate courses in related disciplines (chemistry, environmental science) may be acceptable in satisfying the 33-credit minimum degree requirement in biology. Graduate courses taken at other accredited institutions may also be acceptable for transfer.

Five-Year B.S./M.S. Program

In recognition of the needs for advanced training beyond the bachelor of science level in biological sciences, the following represents a program by which outstanding undergraduates can pursue an accelerated five-year course of study leading to the B.S. and M.S. degrees in Biological Sciences.

1. Undergraduate students who express an interest in this program will be evaluated by our Department Graduate Selection Committee. Those students deemed commendable by the Com-

mittee will be advised as to the correct procedure for successful completion of their B.S. degree, as well as a course of study toward the M.S. degree.

2. The first two years of undergraduate study will be identical to that which is specified for students enrolled in our current four-year B.S. program.

3. The Junior year of study will be essentially the same as that of our four-year B.S. program, except that the student will be expected to take one additional undergraduate elective course each semester. This does not constitute an overload, since 18 credits per semester will not be exceeded. This maneuver will allow for greater flexibility to pursue graduate-level training during the Senior year.

4. During the second semester of Junior year and upon approval and recommendation by the Department Graduate Selection Committee, the student will file formal application to the Graduate School. This does not require the student to have taken the GRE examination. The Committee decision will be based on: (a) overall grade point average, (b) grade point average in selected subjects, (c) recommendations by Department faculty, and (d) a 1-year minimum residency requirement at the University of Lowell. Upon approval and recommendation by the Dean of the Graduate School, the student may be allowed to pursue graduate studies during the Senior year and officially becomes a Provisional Graduate Student in the second semester of the Senior year.

5. During the Senior year, the student will be permitted to take up to two graduate-level courses each semester, which will be applied towards the M.S. degree. Although advanced undergraduate (i.e. 400 level) courses are acceptable, no more than two such courses will be allowed towards the M.S. degree. It should be emphasized that the total numbers of credits for the combined degrees must be greater than the minimum numbers of credits required for the undergraduate B.S. degree. For example, if the University B.S. requirement is 120 credits, the student may, with approval, transfer any additional graduate-level credits toward the M.S. degree, excluding those employed for the B.S. degree.

6. Upon completion of the fourth year of study, assuming that all Department and University requirements have been met, the student will be awarded the B.S. degree and may then be recommended for full matriculation status by the Department Graduate Selection Committee and the Dean of the Graduate School, prior to the fifth year of study. If the student chooses not

to continue toward the M.S. degree (or fails in the fifth year), this does not alter receipt of the B.S. degree.

7. Although the options exist for taking an overload in any semester and/or registration for one or more summer sessions, they are not a requirement of this program. However, students wishing to gain a full research experience will be encouraged to initiate their research as early as possible (i.e. during the Junior to Senior year summer session), which is a distinct advantage of this accelerated program.

8. During the fifth year, as in our standard M.S. degree program, the student may undertake the (a) thesis option (9-12 semester hours of Graduate Research), or (b) non-research option (0 semester hours of Graduate Research). In any case, the student will be required to take a 3-credit Laboratory Instrumentation course (81-530), two 2-credit Graduate Seminar courses (81-601, 81-602) and must satisfy the 33-credit minimum M.S. degree requirement. If the student has gained full matriculation status, he/she would be eligible for a Teaching Assistantship during the fifth year. Upon completion of all Departmental and Graduate School requirements, the student will be awarded the M.S. degree.

Doctor of Philosophy Degree Program (Biochemistry Option).

This option is tentative and subject to change. Students should acquaint themselves with latest departmental policy. The Department of Biological Sciences and the Department of Chemistry have developed a program in Biochemistry which results in the award of a Ph.D. in Chemistry. This program draws upon the special and diverse talents of both faculties, and provides students with both in-breadth class work and in-depth thesis research. Emphasis is on the application of modern techniques and concepts of physical and chemical science to the solution of problems of current interest in biology and medicine.

Requirements for admission to the program

In addition to the general requirements outlined by the Graduate School, the student must have completed requirements for an acceptable B.S., B.A. or M.S. degree in chemistry, biology, or biochemistry. Students with a Bachelor's, or Master's degree in biology will be expected to have completed two semesters each of general, organic, and physical chemistry, while those with a de-

gree in chemistry will be expected to have completed at least two semesters of an introductory biology course. Deficiencies in undergraduate course work should be removed within the first year of residence.

Academic Standards for Retention in the Biochemistry Program
These are the same as those required by the Graduate School. C or better must be achieved in undergraduate level courses in order to remove a deficiency.

Language Requirements
These are outlined under Ph.D. requirements for the Chemistry degree.

Degree Requirements
A minimum of 45 credits of graduate-level work is required prior to awarding the degree. Of these, 27 are exclusive of seminar and thesis and must include the following:

A. Required Biochemistry Courses:	Credits
Biochemistry I	3
Biochemistry II	3
Biochemistry Lab	2

B. Required Chemistry courses (*two* of the following must be elected)

84-523	Organic Reaction Mechanisms and Structure	3
84-527	Stereochemistry	3
84-532	Advanced Physical Chemistry	3
84-568	Structural Analysis	3

C. Approved Biochemistry Electives (A total of 13 credits must be chosen)
Any graduate-level course offered by the Chemistry Department
Any graduate Biochemistry course offered by Department of Chemistry or Biology*

*Of the graduate courses in Biological Sciences listed in this catalog, those which have an asterisk (*) are approved Biochemistry electives.

Seminars
During each semester in residence all full-time students must register for a 1-credit seminar course. The student is expected to pre-

pare two one-hour presentations during his residence, and to attend one seminar each week, as required by the Chemistry Department.

Journal Club

Once admitted to candidacy for the Ph.D. (generally at the end of the second year) each student will participate in a journal club to discuss recent articles from assigned journals.

Research

A. *Initiation of Research*

The dissertation research of each Ph.D. candidate may be initiated after one semester of residence. This research must be initiated by the end of the first year in residence. The choice of research preceptor will be made by the student who should attempt to identify the area of his research interest and particular research group which may be suitable for pursuing his research goals.

B. *Advisory Committee*

After the student has chosen his research preceptor, an advisory committee will be appointed to monitor the progress of the student's research. The committee will be made up of at least three members, the student's advisor (as chairman of the committee) and one each from the Departments of Chemistry and Biological Sciences. The advisory committee will also be responsible for monitoring qualifying and general examinations for the students.

Examinations

A. *Qualifying Examination for Biochemistry*

If the average letter grade for Biochemistry I and II is less than B, the student is required to pass an oral examination in Biochemistry administered by the student's Advisory Committee. Incoming students wishing to receive credit for an undergraduate biochemistry course may also be requested to pass this examination. Petition to take the examination may be made to the Biochemistry Program Curriculum Committee. Failure to achieve either the necessary letter grade average in Biochemistry I and II, or a passing grade on the qualifying exam will be reason for review of the candidate's status in the program. The student will be advised either to withdraw from the program or to take the examination again.

B. *General Examination*

The general examination is designed to evaluate the student's overall background, his general development as a biochemist with

special reference to current interest in literature, and his preparedness as a scientist. The examination will comprise an oral presentation of an original research proposition on a topic other than that of the student's thesis work. The student will prepare an outline of his proposed research (to be distributed to the advisory committee at least a week before examination) and will defend his arguments orally in front of the examination committee and other interested faculty members. However, questions are not necessarily limited to the area of the proposal. In the event of failure, the student may petition to retake the exam. This exam must be completed before the start of the third year in the program.

Admission to Candidacy for the Doctorate

To be admitted to candidacy for the doctorate, a student must:

1. Complete all required courses with necessary grade point average
2. Pass the General Examination and, if necessary, the qualifying examination
3. Fulfill the language requirement (as outlined by the Chemistry Department)
4. Secure approval of his/her research preceptor and the biochemistry committee

When these requirements have been fulfilled, the Biochemistry Program Curriculum Committee will recommend that the graduate coordinator of the Department of Chemistry notify the Dean of the Graduate School to place the student on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

Research Programs and Facilities

Members of this department are engaged in research programs in the following areas in which opportunities for advanced degree thesis or project research are offered:

Chemotherapy, epidemiology and physiology of parasitic diseases

Lipid biochemistry and cardiovascular disease

Bacteriophage biochemistry and control of gene expression

Microbial genetics; ultrastructure and function of viral chromosomes

Immunobiology of host-parasite relationships

Metabolic regulation, nutritional biochemistry and cell biology

Ecology, aquatic biology and ecological physiology

Erythropoietic control mechanisms; kinetics of stem cell proliferation and differentiation; hyperbaric oxygen-induced hemolysis

Developmental and chemical control of aging and senescence in plants

Biological ultrastructure; cytology; plant anatomy and physiology; biomembranes

The department is housed in two new science buildings containing modern teaching and research facilities, office research modules, service areas such as animal quarters, greenhouse, X-ray facilities, temperature-controlled animal and plant cell incubation equipment and dark rooms. The department also maintains a primate center for the study of parasitic diseases. Research instrumentation includes electron microscopes (transmission and scanning), ultracentrifuges, UV-visible spectrophotometers, gas chromatograph, fluorometer, atomic absorption spectrophotometer, liquid and deep-well crystal scintillation spectrometers, interference and UV-phase microscopes, microdensitometer, Coulter Counter, and electrophoresis and chromatography equipment.

Faculty

Each member of the graduate faculty in the Department of Biological Sciences has a distinguished research career as evidenced by numerous publications, attendance and participation in research conferences and acquisition of grants and contracts. Many have served as fellows in postdoctoral research programs. Faculty have affiliation and research collaborations with Harvard Medical School, Harvard School of Public Health, Boston University, Sidney Farber Cancer Institute, Brigham Young University, Univer-

sity of Texas, Mahidol University (Thailand), Academy of Medical Sciences (U.S.S.R.), U.S. Naval Research and Development Center, Air Shams University of Cairo, Egypt and The University of Jordan (Amman, Jordan).

Courses of Study

(An asterisk (*) indicates approved Biochemistry Ph.D. Program electives)

81-501/502 Selected Topics in Biology *Staff* **(3-0) (3-0)6**
Prerequisite: Permission of Instructor
Current topics in various fields of biology presented in lecture, seminar or discussion groups. Subject matter varies depending on interests of instructors and needs of students. May be repeated for credit when course content differs.

***81-503 Biochemistry of Metabolic Disorders** *Hojnacki* **(3-0)3**
Prerequisites: 81-419 and 81-252
This course deals with the biochemical alterations, pathophysiology, methods of detection and treatment of the following disturbances in metabolism: diabetes, obesity, alcoholism, senility, gallstone formation, fetal lung maturity, atherosclerosis, familial hyperlipoproteinemia, LCAT deficiency, Tangier disease, glycogen storage diseases, Tay-Sachs disease and Niemann-Pick disease. Current concepts in total parenteral nutrition will also be considered.

81-506 Physiological Ecology *Mallett* **(3-0)3**
Prerequisites: 81-252, 81-331 or equivalent
A consideration of physiological evolutionary and environmental aspects of interactions between organism and environment with special emphasis on homeostatic adaptations to biotic and abiotic environmental fluctuations. Concurrent registration in 81-508 is required for Biology majors.

81-508 Physiological Ecology Laboratory *Mallett* **(0-3)1**
A series of laboratory investigations designed to illustrate basic homeostatic adaptations enabling organisms to maintain internal constancy in a variable environment.

81-510 Limnology *Mallett* **(3-0)3**
Prerequisites: 81-112 and either 81-331 or 81-315
An introduction to freshwater as a biogeochemical environment considering the geology, chemistry and physics of inland waters as they affect the ability of the medium to sustain life. Particular attention is addressed to basin and channel morphometry, thermal, photic, hydrologic and solvent properties of the medium. Floral and faunal components of the system are considered from populational and community aspects, evolutionary development and specific adaptations to particular niches in standing and flowing waters.

81-512 Limnology Laboratory *Mallett* **(0-3)1**
A series of laboratory exercises designed to emphasize the material covered in 81-510.

***81-518 Experimental Hematology** *Rencricca* **(3-0)3**
Prerequisite: 81-252 or equivalent
An introduction to the physiology of the erythropoietic system. Emphasis will be given to the proliferation and differentiation of hemopoietic stem

cells with regard to the regulation and maintenance of homeostasis. Abnormalities and perturbations resulting in diseased conditions, such as anemia and polycythemia, will be discussed.

***81-520 Experimental Hematology Laboratory** *Rencricca* **(0-6)2**
A series of laboratory exercises and projects designed to employ basic and advanced techniques in hematology and which emphasize the material covered in 18-518.

***81-522 Plant Physiology** *Kamien* **(3-0)3**
Prerequisite: 84-222 or equivalent
Co-requisite: 81-524
A critical study of the physiological processes which occur in living plants, with emphasis on the angiosperms. Topics treated are growth and development, water relations, mineral nutrition, respiration, photosynthesis, and nitrogen metabolism.

***81-524 Plant Physiology Laboratory** *Kamien* **(0-3)1**
A series of laboratory experiments and analyses designed to illustrate the material covered in 81-522.

***81-529 Biochemical Aspects of Heart Disease** *Hojnacki* **(3-0)3**
Prerequisites: 81-419 and either 81-252 or 81-324
This course emphasizes a comparison of normal and abnormal functions of the heart and blood vessels. Topics include a discussion of the relationship between nutrition, circulating fat and heart disease, aorta cell metabolism, metabolism of fat in the human body, risk factors in coronary heart disease, and current biochemical methods employed in cardiovascular research.

***81-530 Laboratory Instrumentation** *Staff* **(1-6)3**
Required of all graduate students
A course designed to acquaint the student with a variety of research techniques and instrumentation used in the biological laboratory, their theory and practical applications.

***81-531 Regulation in Animal Metabolism** *Lynch* **(3-0)3**
Prerequisite: 81-419 or equivalent
Lectures and discussion related to factors determining direction and rate of flux of substrates through a variety of interrelated metabolic pathways. Both hormonal and non-hormonal mechanisms involved in generating an integrated metabolic response to changes in nutrient availability will be examined. Emphasis will be on studies in mammalian systems.

***81-541 Topics in Cell Biology** *Rivera* **(3-0)3**
Prerequisite: 81-419, 81-371, or equivalent
The fundamental structure and function of the cell will be discussed in detail. Some of the topics to be discussed are: 1. The anatomy and biochemistry of cellular membranes, 2. Transport mechanisms, 3. Systems developed by various life forms for motility, 4. Properties of excitable cells, 5. Energy transduction mechanisms. Wherever possible, comparisons between the biology of normal and transformed cells will be made. May be repeated for credit when content varies.

***81-542 Cytology** *Rivera* **(3-0)3**
Prerequisite: 81-419 or equivalent
Co-requisite: 81-544
The structure of eukaryotic cells. Study of cell membranes and organelles they define; specialized organelles for energy capture and transduction;

aspects of histochemical and biochemical studies of organelles at the optical and electron microscopic level. An introduction into cytogenetics and nuclear cytology; a brief discussion of prokaryotic cells. A substantial library investigation of some aspects of cell structure and/or function is required.

***81-544 Cytology Laboratory** *Rivera* **(0-3)1**
Co-requisite: 81-542
Introduction to the optical microscope as an analytical tool. Individual laboratories designed to acquaint the student with the analysis of biological ultrastructure at the optical and electronmicroscopic level. Cell fractionation. Chromosome preparations. One substantial ultrastructural analysis required.

***81-552 Recombinant DNA Techniques** *Skare* **(3-0)3**
Prerequisites: 81-419, 81-335
A study of the principles and specialized techniques of purifying, manipulating, and cloning of recombinant DNA molecules. Includes techniques involving restriction endonuclease mapping of genomes, cloning of DNA fragments from procaryotic and eucaryotic genomes, types of vectors used in genetic engineering, and the applicability of these techniques to solution of various problems in cell biology.

81-561 Electron Microscopy - Theory *Rivera* **(3-0)3**
Prerequisites: 81-419, 81-420, and permission of Instructor
An introduction to the theory of electron microscopes and electron optics. Preparation of biological specimens for electron miscroscopic viewing and photography. Analysis of data obtained with electron microscopic techniques. Applications in biology will be discussed.

81-562 Electron Microscopy - Laboratory *Rivera* **(0-9)3**
Prerequisite: 81-561, Permission of Instructor
Operation of Scanning and Transmission Electron Microscopes. Project required of all students. Use of ancillary optical equipment.

81-564 Experimental Hematology: A Study of Current Literature *Rencricca* **(3-0)3**
Prerequisite: 81-518 or equivalent
This course will involve group discussions of the recent scientific literature in experimental hematology. Cellular and humoral mediators of blood cell production will be assessed relative to hemopoietic stem cell proliferation, differentiation and migration, with an emphasis on erythropoiesis. Papers dealing with abnormalities and perturbations resulting in diseased states will be included for discussion.

***81-565 Role of Micronutrients in Mammalian Nutrition** *Lynch* **(3-0)3**
Prerequisites: 81-252, 81-419 or equivalent
The biochemical mode of action of selected vitamins and minerals as well as mechanisms involved in regulating their absorption, conservation, and metabolism will be emphasized. Where possible their significance in the context of human nutrition and disease will be discussed.

***81-572 Virology** *Skare* **(3-0)3**
Prerequisites: 81-419; either 81-201 or 81-335
A study of bacterial and animal viruses including viral structure, modes of replication, biochemistry of the infected cell, genetic properties, and

viral oncogenesis. Emphasis is on virus-cell interactions at the molecular level. A library investigation of a current topic is required.

***81-574 Virology Laboratory** *Skare* **(0-3)1**
A series of laboratory experiments covering current techniques in bacterial and animal virology. Included are virus propagation and titration, biochemical, biophysical, and genetic analysis of viral nucleic acids and proteins, and cell culture techniques.

***81-584 Biochemical Genetics** *Wong* **(3-0)3**
Prerequisites: 81-419, 81-335 or equivalent
The biochemical structure and function of the eukaryotic genome will be discussed. Subject areas include the structure of chromatin, the function of histones and nonhistones and their interaction with DNA, DNA sequence, structure and function of RNA transcripts, and mechanism of DNA replication, RNA transcription, RNA processing and protein synthesis. DNA. DNA reassociation and RNA. DNA hybridization kinetics will also be discussed.

***81-585 Eukaryotic Gene Expression** *Wong* **(3-0)3**
Prerequisites: 81-419, 81-335 or equivalent
A study of the regulation of gene expression in eukaryotic cells. Emphasis will be given to the regulation of gene expression at transcriptional and posttranscriptional levels during hormonal activation, cell development and cell transformation. The structure and the mechanism of expression of histone, ribosomal RNA, globin and ovalbumin genes will also be discussed.

***81-586 Cellular Immunology** *Coleman* **(3-0)3**
Prerequisites: 81-593, 81-595, or equivalent
Categories, cells, mediators, signals, interactions and regulation of immunological reactions involving cell-mediated immunity.

***81-588 Cellular Immunology Laboratory** *Coleman* **(0-3)1**
A project laboratory designed to illustrate aspects of material covered in 81-586.

***81-593 Immunobiology** *Coleman* **(3-0)3**
Prerequisites: 81-201, 81-419, or equivalent
A study dealing with the biology of the immune response with sections on antibody production, reaction with antigen, suppression, tolerance, protection and injury. Concurrent registration in 81-595 is required for Biology majors.

***81-595 Immunobiology Laboratory** *Coleman* **(0-3)1**
A series of basic laboratory exercises dealing with the preparation, isolation and characterization of antigens, antibodies and effector cells.

81-601, 602 Graduate Seminar in Biology *Staff* **(2-0) (2-0)4**
Required of all graduate students
Presentation of individual reports by students on advanced topics, original research, or journal articles.

***81-651, 652 Selected Topics in Biology** *Staff* **(3-0) (3-0)6**
Prerequisite: Graduate students only
Permission of Instructor
Selected topics and recent advances not covered in regular courses. Content varies from year to year so that students may, be repeated enrollment, acquire a broad knowledge of contemporary biology. Recent offer-

ings have been: eucaryotic developmental genetics, recombinant DNA, and experimental hematology: a study of current literature.

81-701 Graduate Research in Biology *Staff* **(0-9)3 to (0-18)6**
An independent investigation of a problem which has been approved as a suitable subject for a Master's Thesis.

81-702 Graduate Project in Biology *Staff* **(0-3)1 to (0-9)3**
An independent study or laboratory project which has been approved as a suitable subject for a Master's Project.

***81-751, 752 Problems in Biology** *Staff* **(0-3)1 to (0-9)3**
Prerequisite: Permission of Instructor
Special research or laboratory projects, or extensive literature surveys, undertaken by the student to expand his knowledge in specific fields not necessarily related to his thesis.

82-551 Human Sexuality: Current Perspectives *Kamien* **(3-0)3**
(This course is offered for students not working towards a degree in Biological Sciences and cannot count towards the M.S. degree in Biological Sciences). The biological basis, psychological determinants, and sociological implications of human sexual expression are examined. An extensive project, showing evidence of in-depth academic investigation, will relate and apply the course content to the particular professional involvement and concerns of each participant.

DEPARTMENT OF CHEMISTRY

Department Chairperson: Albert D. Kowalak, *Associate Professor;* B.S., College of William and Mary; M.S., Ph.D., Virginia Polytechnic Institute.

Department Coordinator: Stuart B. Clough, *Professor of Chemistry;* B.S., University of Massachusetts; M.Ch.E., University of Delaware; Ph.D., University of Massachusetts.

Faculty

William W. Bannister, *Professor;* B.S., Ph.D., Purdue University.

Eugene F. Barry, *Professor;* B.S., Villanova University; Ph.D., University of Rhode Island.

Alexandre Blumstein, *Professor;* B.S., Sorbonne, France; Ph.D., University of Strasbourg, France.

Rita B. Blumstein, *Associate Professor;* B.S., Sorbonne, France; Ph.D., University of Delaware.

Martin Isaks, *Associate Professor;* B.S., Purdue University; M.S., Iowa State University; Ph.D., University of Cincinnati.

Stanley C. Israel, *Professor;* B.S., Parsons College; Ph.D., Lowell Technological Institute.

Kuang-Pang Li, *Assistant Professor;* B.S., M.S., National Taiwan University; M.S., Ph.D., University of Illinois.

Irving Lipschitz, *Associate Professor;* B.A., M.S., New York University; Ph.D., Virginia Polytechnic Institute.

Robert Litman, *Assistant Professor;* B.S., Brooklyn College; Ph.D., City University of New York.

James B. Pierce, *Professor;* B.S., Thiel College, M.S., Ph.D., Case Institute of Technology.

Chong Wha Pyun, *Professor;* B.S., M.S., Seoul National University, Korea; Ph.D., Brown University.

Harry Rubinstein, *Professor;* B.S., Brooklyn College, Ph.D., Purdue University.

Joseph C. Salamone, *Professor;* B.S., Hofstra University, Ph.D., Polytechnic Institute of Brooklyn.

Samuel P. Sawan, *Assistant Professor;* B.S., Ph.D., University of Akron.

Thomas E. Stone, *Assistant Professor;* B.S., B.A., University of California, Irvine; M.S., Ph.D., Oregon Graduate Center.

Arthur C. Watterson, Jr., *Professor;* B.S., Geneva College; Ph.D., Brown University.

Shan S. Wong, *Assistant Professor;* B.S., Oregon State University; Ph.D., Ohio State University.

Master of Science Degree Program

This program provides opportunity for advanced study and research training in chemistry, both general and specialized. Provision also is made for the student to elect certain advanced subjects in related fields of mathematics, physics, and engineering.

Diagnostic-Evaluation Examinations

During the week of registration, each entering student must present himself for written examinations in four fields: organic, physical, inorganic and analytical chemistry. The examinations are the ACS Graduate Level Placement Exams and are used to help plan the student's program.

Credit Requirements

Of the 18 credit minimum, exclusive of research and seminar, required in listed subjects, a minimum of 15 credits must be taken in chemistry. The remaining course credits (3 or more) may be taken in chemistry or in related fields such as physics, mathematics, biology or engineering. Credit normally is not allowed for 400 level subjects in chemistry except for those designated in the catalogue or approved by a student's adviser. Each graduate program in chemistry must include at least three advanced subjects from 3 of the following areas: Organic Chemistry, Inorganic Chemistry, Analytical Chemistry, Physical Chemistry, Biochemistry or Polymer Chemistry, unless such requirements have been met previously. Depending upon student's performance on the diagnostic examinations, the student's advisory committee may recommend that he/she take additional courses in the areas of deficiency.

Although the design of the student's program is the responsibility of his Advisory Committee, the following listing provides a suggested core of subjects:

Chemistry — First Semester Subjects

84-514	Advanced Analytical Chemistry	(3-0)3
84-515	Chemical Literature	(3-0)2
84-523	Organic Reaction Mechanisms and Structure	(3-0)3
84-531	Advanced Physical Chemistry	(3-0)3
84-601	Chemistry Seminar	(1-0)1
84-701	Graduate Research in Chemistry	(0-9)3

Chemistry — Second Semester Subjects

84-543	Advanced Inorganic Chemistry	(3-0)3
84-516	Advanced Laboratory Technique	(1-6)3
84-524	Organic Synthesis	(3-0)3
84-544	Chemical Applications of Group Theory	(3-0)3
84-602	Chemistry Seminar	(1-0)1
84-702	Graduate Research in Chemistry	(0-9)3

Language Requirements

There is no language requirement for the M.S. degree in Chemistry.

Thesis Examination

Each candidate for the Master of Science degree in Chemistry must appear for an oral examination in the field of his/her thesis before an examining committee appointed by the Department Chairperson from the graduate faculty in chemistry. This examining committee normally will include the student's advisory Committee plus an additional member of the graduate faculty. The chairperson for the examination shall be the research adviser. While only members of the examination committee and the dean of the Graduate School may conduct the examination, all faculty members may attend. The examination is held after the thesis has been accepted and within a period of two weeks prior to the close of the final semester. Application to take the examination must be filed by the student with the Department Chairperson at least one month prior to the close of the last semester. Each student has the right to one re-examination within a period of one year.

Doctor of Philosophy Degree Program

The doctoral program in chemistry is designed to provide the student with a background in advanced course work and chemical laboratory techniques that will prepare him to carry out, under the

guidance of experienced scientists, an original, independent investigation that will lead to an acceptable contribution to the body of contemporary knowledge.

Plan of Program

The doctoral degree normally requires four years of study beyond the bachelor's degree or a minimum of two to three years beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through conference with the Advisory Committee (or with his temporary adviser).

All students entering the doctoral program must take the complete set of evaluation examinations given during the week of registration as described in the section relating to the Master of Science program in Chemistry.

The initial part of the student's program, normally completed at the end of two years of study, is devoted to formal course work. The first year is usually given to subjects in the major branches of chemistry in preparation for area (candidacy) examinations. The second year is devoted primarily to advanced subjects in a special field of concentration.

The second and final part of the program is devoted principally to research leading to the doctoral thesis. However, the student is encouraged to begin research as early as possible in the program of study.

Language Requirements

Demonstrate satisfactory reading ability in one foreign language (level two), and acquire facility in one additional research tool. This may be a second language, computer programming, statistics, advanced mathematics, or other skills acceptable to the student Advisory Committee and approved by the Department.

Credit Requirements

Of the 45 minimum credit requirements, a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with at least 18 to be taken in chemistry. The remaining course credits (9 or more, with a student's Advisory Committee having the authority to add 6 additional credits to the minimum in special situations) may be taken in chemistry or in a related field such as biology, physics, mathematics or engineering. Credit is not normally allowed for undergraduate subjects in chemistry except for those so designated in the catalogue. Research credits would then make up the remainder of the 45 credit requirements. Planning

the program of courses with the student is the responsibility of a student's Advisory Committee.

Written Area Examinations
Upon admission to the Ph.D. program the student must pass exams in his/her major area of specialization. The method of conducting these area exams is decided by the staff in each field of specialization. Analytical majors take a six part comprehensive exam. Organic majors take a series of cumulative exams which are designed to test the student's ability to handle information. A student is given eight chances to pass four examinations with a mark of pass or fail given for each examination. Students must take the examinations consecutively.

Research Proposition
As part of the area examination(s) a Ph.D. candidate must present an oral defense of an original research proposal. With the aid and advice of the Advisory Committee the student selects a suitable subject for investigation, completes a literature survey, outlines the method of approach, and suggests possible results and conclusions. The oral defense of this proposal is conducted by the student's Advisory Committee with other faculty members in attendance. It is taken after completion of area exams.

Chemistry Seminar
During each year of residence the student is required to attend and to participate in 84-601 -602, Chemistry Seminar, (1-0) (1-0) 2.

Course Offerings and Distribution

As a basis for the candidacy examinations the following core courses are recommended for the first-year students in the doctoral program:

84-532 Advanced Physical Chemistry	(3-0)3
84-514 Advanced Analytical Chemistry	(3-0)3
84-515 Chemical Literature	(2-0)3
84-516 Advanced Laboratory Techniques	(1-3)2
84-523 Organic Reaction Mechanism and Structure	(3-0)3
84-524 Organic Synthesis	(3-0)3
84-543-544 Modern Inorganic Chemistry	(3-0) (3-0)3

Each student in the Ph.D. program shall take both Advanced Physical Chemistry and Advanced Organic Chemistry and two courses from Advanced Inorganic, Advanced Analytical,

Biochemistry, or Polymer Chemistry unless such requirements have been met previously.

If the results from the diagnostic examinations indicate adequate background in any of the above subjects, substitution by a more advanced subject in the 500 series is recommended.

Additional subjects in chemistry or in the field of the minor may be taken in the first year if desired, provided the prerequisites are met.

In the second year, subjects supporting concentration in specific fields are available as follows:

Analytical Chemistry

84-585-586 Nuclear and Radiochemistry	(3-4)4
84-519 Environmental Chemistry	(3-0)3
84-526 Theory and Applications of Chromatography	(3-0)3
84-568 Structural Analysis	(3-0)3

Organic Chemistry

84-521 Physical Organic Chemistry	(3-0)3
84-527 Stereochemistry	(3-0)3
84-561 Advanced Organic Synthesis	(3-0)3
84-563 Chemistry of Natural Products	(3-0)3
84-565 Heterocyclic Chemistry	(3-0)3
84-568 Structural Analysis	(3-0)3

Physical Chemistry

84-531 Statistical Thermodynamics	(3-0)3
84-534 Quantum Chemistry	(3-0)3
84-535-536 Advanced Topics in Physical Chemistry	(3-0) (3-0)6
84-540 Chemical Kinetics	(3-0)3

Biochemistry

84-419 Biochemistry	(3-0)3
84-538 Biochemical Mechanisms	(3-0)3
84-563 Chemistry of Natural Products	(3-0)3
84-651 Selected Topics in Biochemistry	(3-0) (3-0)6

Candidacy for the Doctorate in Chemistry

To be admitted to candidacy for the doctorate, a student must:

1. Complete the first year's core of recommended subjects and have satisfactory record in undergraduate training, graduate seminar and collateral reading.
2. Pass the diagnostic evaluation and area examinations.
3. Fulfill the language requirements.
4. Secure the approval of the Advisory Committee and the Department Head.

When these requirements have been fulfilled, the Department Head notifies the dean of the Graduate School in writing and recommends that the student be placed on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

Courses of Study

84-532 Advanced Physical Chemistry *Pyun* **(3-0)3**
Prerequisite: Permission of Instructor
Extension of introductory physical chemistry. Open to seniors and first-year graduate students in chemistry and related fields. Emphasis is placed on quantum chemistry of atoms and molecules as well as on classical and statistical thermodynamics.

84-434 Colloid Science and its Environmental Applications *A. Blumstein* **(3-0)3**
Prerequisite: Permission of Instructor
An introduction to the fundamentals of colloid and interface science. Topics discussed include solid/gas, solid/liquid, and liquid/liquid interfaces, association colloids, emulsion suspension, aerosols, smog and foams. Additional topics include applications of colloid science to environmental problems, flocculation and stability, adsorption and ion exchange, ultrafiltration, reverse osmosis, and electro-kinetic phenomena.

84-585-586 Nuclear and Radiochemistry *Litman* **(3-4)4**
Prerequisite: 2 semesters of undergraduate Physical Chemistry
Fundamentals of radiochemistry, including radioactivity, atomic nuclei, nuclear reactions, reactors, and radiation detection and measurement, with emphasis on the use of radioactive materials in chemical applications. Designed primarily for majors in chemistry and allied fields.

84-513 Spectroscopy *Lipschitz* **(3-0)3**
Prerequisite: 84-431-432 or equivalent
A presentation of molecular spectra and molecular structure is presented to illustrate the empirical results and the theoretical background necessary to interpret the results.

84-514 Advanced Analytical Chemistry *K.P. Li* **(3-0)3**
Prerequisite: 84-431 or equivalent
Advanced analytical techniques based on physical-chemical principles and utilizing instrumental methods wherever applicable. The analytical use of complexes, radiant energy methods, electrochemistry, chromatography, polarography, analytical applications of radioisotopes, and physical methods of separation.

84-515 Chemical Literature *Rubinstein* **(2-3)3**
Prerequisite: Permission of Instructor
Use of the chemical library, journals, reference works and other technical publications pertaining to chemical subjects. Exercises in finding, assembling, and using such data. The student will be expected to assimilate the use of automated information retrieval and conduct computer assisted literature searches.

84-516 Advanced Laboratory Techniques *Staff* **(1-6)3**
Prerequisite: Permission of Instructor
A study of the theory and application of the more advanced techniques and equipment in the preparation and purification of organic compounds, including high efficiency fractionation, vacuum and molecular distillation, hydrogenation and reactions in inert atmosphere.

84-517 Glass Working *Rubinstein* **(1-0)1**
Prerequisite: Permission of Instructor
Fundamental techniques in the preparation and assembling of glass apparatus.

84-519 Environmental Chemistry *Litman* **(3-0)3**
Prerequisite: 84-342, 84-313 or equivalent with Permission of Instructor
A study of the reactions involving atmospheric and aquatic pollutants. Included are such topics as the oxides of nitrogen, carbon, and sulfur, particulate matter in air, and equilibria occurring in natural waters. Approved "wet" and instrumental methods of analysis of pollutants of current interest are also presented.

84-521 Physical Organic Chemistry *Staff* **(3-0)3**
Prerequisite: 84-523-524 or equivalent
Modern and classical methodology in the study of organic reactions. Linear free energy relationships, tracer methods, orbital symmetry and other selected topics will be covered.

84-523 Organic Reaction Mechanisms and Structures *Staff* **(3-0)3**
For graduate students only
Designed to provide insight into how reactions occur and how the reactions mechanism is studied. Emphasis is placed on bonding, substitution and elimination processes, stereochemistry, and conformational analysis.

84-524 Organic Synthesis *Staff* **(3-0)3**
For graduate students only
Mechanism, scope and limitations of important selected types of reactions, and designs of synthetic sequences. Emphasis is placed on reduction, oxidation, halogenation, alkylation, and acrylation.

84-526 Theory and Applications of Chromatography *Barry* **(3-0)3**
Prerequisite: Permission of Instructor
A treatment of the theory underlying chromatographic separations and processes. Included are such topics as gas-liquid, gas-solid, thin-layer, column and gel permeation chromatography. Applications of the various chromatographic methods are discussed.

84-527 Stereochemistry *Staff* **(3-0)3**
The fundamental concepts of optical and geometrical isomerism and the relationship of the stereostructures to the physical and chemical properties of organic compounds.

84-531 Statistical Thermodynamics *Staff* **(3-0)3**
Prerequisite: 84-432 or equivalent
Fundamentals of equilibrium statistical mechanics, classical and quantum statistics. Molecular theories of gases, crystals and liquids, with emphasis on chemical aspects. Electrolyte and non-electrolyte solutions, polymer and polyelectrolyte systems, chemical equilibria and reaction rate processes. Also, introduction to nonequilibrium statistical theories.

84-534 Quantum Chemistry *Staff* **(3-0)3**
Prerequisite: 84-431 or equivalent
Principles and methods of quantum mechanics with special attention to chemical applications, such as electronic nature of atoms and molecules, vibrations and rotation of molecules, and interaction of radiation with matter.

84-538 Biochemical Mechanisms *Wong* **(3-0)3**
Prerequisite: 84-422-523, or Permission of Instructor
Selected biochemical reactions will be presented from the point of view of organic reaction mechanisms. Kinetics, coenzyme and enzyme catalysis and mechanisms of oxidative phosphorylation will be emphasized. Offered in the Spring.

84-535-536 Advanced Topics in Physical Chemistry *Staff* **(3-0) (3-0)6**
Selected topics and recent advances in physical chemistry. Selection of topics is at the discretion of the instructor.

84-540 Chemical Kinetics *Kowalak* **(3-0)3**
Prerequisite: 84-432 or equivalent
The theoretical and empirical treatment of chemical kinetic data as well as the methods of obtaining these data. Determination of the order of reactions, factors influencing rates, application of rate studies in establishing hypotheses for reaction mechanism, collision theory, and absolute rate theory.

84-543 Modern Inorganic Chemistry *Kowalak* **(3-0)3**
Prerequisite: Permission of Instructor
Similar to 84-443-444 but designed specifically for graduate students. Emphasis is placed on the theory of the chemical bond, bonding in complexes, coordination theory, spectroscopic methods, non-aqueous solvent systems.

84-544 Chemical Applications of Group Theory *Staff* **(3-0)3**
Prerequisite: 84-334, 84-543 or equivalent
Properties of groups as applied to chemical systems. Development of the ligand field theory and prediction of electronic and vibrational-rotational spectra.

84-563 Chemistry of Natural Products *Watterson* **(3-0)3**
Prerequisite: 84-568, 84-311 or equivalent
An advanced subject covering the proof of structure of various types of natural products, approaches to the total synthesis of some and also the biosynthetic pathways.

84-565 Heterocyclic Chemistry *Watterson* **(3-0)3**
Prerequisite: Permission of Instructor
Classification, nomenclature, structure, synthesis and utility of the more important classes of heterocyclic compounds.

84-568 Structural Analysis *Watterson* **(3-0)3**
Prerequisite: Permission of Instructor
Practical application of instrumental data in the determination of the structure of organic compounds. Includes mass spectroscopy, ultraviolet spectroscopy, infrared spectroscopy and nuclear magnetic resonance spectroscopy.

84-601-602 Chemistry Seminar *Staff* **(1-0) (1-0)2**
Required of all graduate students
Presentation of current topics by visiting scientists, staff and graduate students.

84-651 Selected Topics in Chemistry *Staff* **(3-0)3**
Prerequisite: Permission of Instructor
Advanced topics in the various fields of chemistry. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary chemistry.

84-701 Graduate Research in Chemistry *Staff* **(0-9) (0-9)6**
An independent investigation of a problem by the student in conference with a faculty adviser and approved by the Department Chairperson. A clear and systematic written presentation of the results is required.

84-751 Advanced Projects in Chemistry *Staff* **(0-3) (0-3)2**
Special projects laboratory undertaken by a student to expand his knowledge in specific fields not necessarily related to his thesis. Content of project and hours assigned must be approved by the Department Head.

Polymer Science (Department of Chemistry)

Master of Science in Polymer Science

The Polymer Science Program of the Department of Chemistry offers the student a unique opportunity for advanced study and research training in the rapidly growing field of macromolecular science. Provision is made to include the broadest coverage of both practical and theoretical aspects of polymer science, taking advantage of the unique facilities at the University of Lowell in chemistry of macromolecules, plastics engineering and other related fields.

Diagnostic-Evaluation Examinations
During the week of registration each entering student must take written examinations in the fields of organic, physical and analytical chemistry. An evaluation examination in polymer science is offered to those who wish to be exempted from 97-503-504. Except for polymer science, the examinations are the ACS Graduate Level Placement Exams.

Course Requirements
A candidate for the Master of Science Degree in Polymer Science must have a minimum of 18 credit hours of course work, exclusive of research and seminar, as well as complete a thesis based upon original research. Of the credit requirement, a minimum of 15 credits must be taken in the Department of Chemistry. The re-

maining course credits (3 or more) may be taken in chemistry (polymer science) or in such related fields as plastics, physics, mathematics, biology or engineering. Credit normally is not allowed for 400 level subjects in chemistry, except for those so designated in the catalogue or approved by a student's adviser. All students must take 97-601-602, Polymer Science Seminar, each year they are in residence. The first semester of Chemistry Seminar, 84-601, may be given concurrently with the first semester of Polymer Science Seminar.

Although the design of the academic program is the responsibility of the student's Advisory Committee, the following listing provides a suggested core of subjects for program development.

First Semester Subjects

97-503	Advanced Polymer Science I	(3-0)3
97-505	Polymer Preparation and Characterization I	(0-4)1
97-511	Biopolymers	(2-0)2
97-553	Organic Chemistry of Macromolecules	(2-0)2
97-601	Polymer Science Seminar	(1-0)1
97-707	Graduate Research in Polymer Science	(0-9)3
84-532	Advanced Physical Chemistry	(3-0)3
84-523	Organic Reaction Mechanisms and Structure	(3-0)3

Second Semester Subjects

97-504	Advanced Polymer Science II	(3-0)3
97-506	Polymer Preparation and Characterization II	(0-4)1
97-512	Properties of Bulk Polymers	(2-0)2
97-602	Polymer Science Seminar	(1-0)1
97-708	Graduate Research in Polymer Science	(0-0)3
87-434	Colloid and Surface Chemistry	(3-0)3
84-524	Organic Synthesis	(3-0)3
26-523	Plastics Processing Techniques	(1-2)2

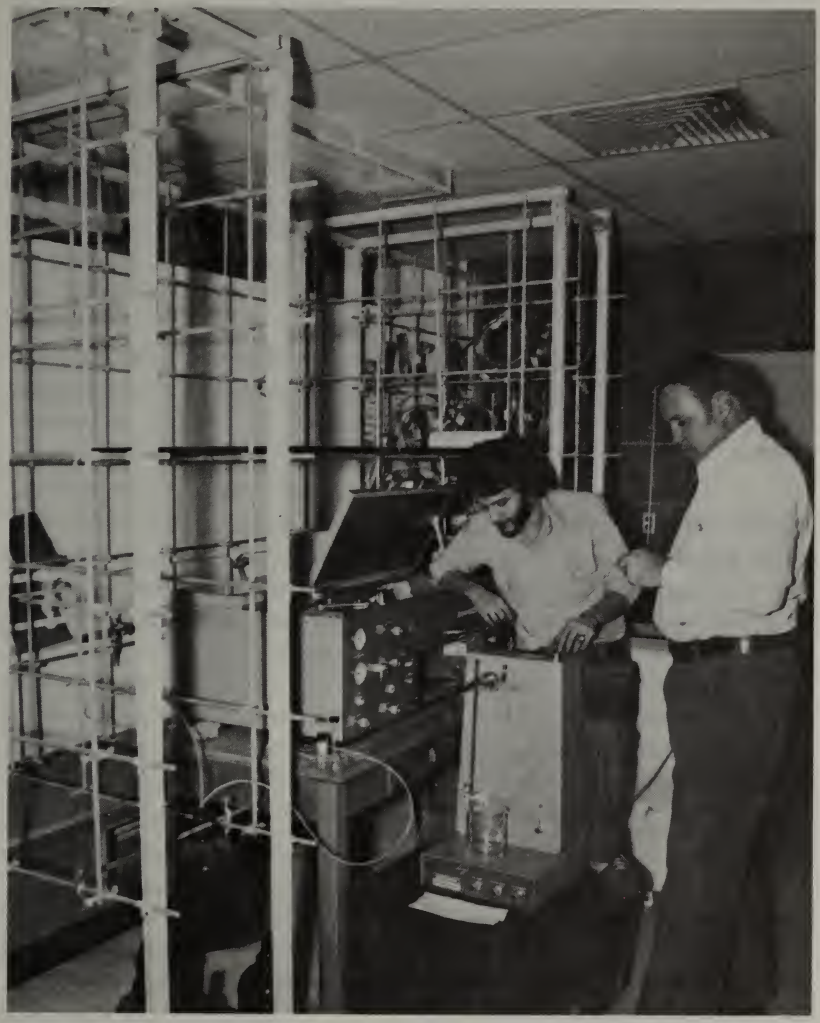
Language Requirements

There is no foreign language requirement for the master's degree in Polymer Science.

Thesis Examination

Each candidate for the master's degree must appear for an oral examination in the field of polymer science before an examining committee appointed by the Department Chairman from the graduate faculty in the Department of Chemistry. The examining committee will include the student's Advisory Committee plus an additional graduate faculty member. The chairman for the examina-

tion shall be the student's thesis adviser. While only members of the examination committee and the dean of the Graduate School may conduct the examination, all faculty members may attend. The examination is held after the thesis has been accepted and within a period of two weeks prior to the close of the final semester. Applications to take the examination must be filed by the student with the Chairman of the Department of Chemistry at least one month prior to the close of the last semester.



Ph.D. - Polymer Science/Plastics Engineering Option

An Interdisciplinary Program

Students in the Ph.D. Program in the Department of Chemistry may elect the Polymer Sceince/Plastics Engineering Option. This doctoral program is organized jointly with the Department of Plastics Engineering. The program is designed to provide students with a background in advanced course work and laboratory techniques that will prepare them to carry out an original investigation leading to an acceptable contribution to the body of contemporary knoweldge in the fields of macromolecules or plastics.

Plan of Program

The doctoral degree normally requires four years of full-time study beyond the bachelor's degree or a minimum of two to three years of full-time study beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through conference with his/her Advisory Committee (or temporary adviser).

All students entering the program must take the ACS Graduate Level placement examinations in organic, physical and analytical chemistry. An evaluation examination in polymer science is given to those who wish to be exempted from 97-503-504.

Requirements for Admission

Requirements for admission into the program are the same as those for students entering other Ph.D. programs in Chemistry. It is the student's responsibility to satisfy any admission requirements stipulated for the Ph.D. in Chemistry.

Undergraduate deficiencies in the student's background must be remedied promptly, usually by the end of the student's second semester. During this period, the student must also complete successfully graduate courses appropriate to his/her background. Students will not be formally admitted to the Ph.D. program if their grade point average is below B.

Advisory Committee

Upon admission the student will be assigned a temporary adviser by the Coordinators of the Graduate Polymer Program and Graduate Plastics Program.

The student's major thesis adviser will become the chairperson of the permanent Advisory Committee and will also be responsible for funding of the research.

For students who elect the Plastics concentration, the permanent Advisory Committee will be composed of four members, two from the Department of Chemistry and two from the Department of Plastics Engineering. One of the committee members from the Chemistry Department will have the responsibility of advising the student in course work and research activities in the field of polymers.

The Advisory Committee will meet at least once each semester to monitor the progress of the student's research.

Program Outline

The initial part of the program (the first two years) is devoted to formal course work. The first year usually is given to subjects in major branches of chemistry, polymers, and plastics in preparation for the student's area (candidacy) examinations. The second year is devoted primarily to advanced subjects in areas relating to Polymers and Plastics.

The second part of the program is devoted principally to research leading to the doctoral thesis. However, the student is encouraged to start research as soon as possible. The student's thesis (dissertation) adviser will be responsible for funding of the research.

Language Requirements

The student must demonstrate satisfactory reading ability in one foreign language (Level Two), and acquire facility in one additional research tool. This may be a second language, computer programming, statistics, advanced mathematics, or other skills acceptable to the Student Advisory Committee and approved by the department.

Written Area Examinations

Upon formal admission to the Ph.D. program the student must pass cumulative area examinations. The examinations must be taken within one semester of finishing the formal course work and must be taken consecutively.

Each student must also present an oral defense of an original research proposal.

Course Requirements

Of the 45 minimum credit requirements a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with at least four courses to be taken in Chemistry and Polymer Science

(84 and 97 prefixes). The remaining course credits may be taken in Chemistry or in the courses listed below. Credit normally is not allowed for undergraduate subjects in Chemistry except for those so designated in the catalogue. Research credits would then make up the remainder of the 45 credit requirement. The program of courses is the responsibility of a Student's Advisory Committee and must include advanced subjects in the appropriate areas of Chemistry, Polymers, and Plastics. When it is necessary to carry less than the normal credit load of 8 per semester, the student must apply to the Chairman of the department through the Chairman of his/her Advisory committee for approval.

Required Courses

The student must take the following core courses:

84-523	Organic Reactions	(3)
	or	
84-568	Structural Analysis	(3)
84-531	Advanced Physical Chemistry	(3)
97-503	Advanced Polymer Science I	(3)
97-504	Advanced Polymer Science II	(3)
97-505	Polymer Preparation & Characterization I	(1)
97-506	Polymer Preparation & Characterization II	(1)
97-512	Bulk Properties of Polymers	(3)
	or	
25-503	Mechanical Behavior of Polymers	(3)
26-506	Polymer Structure	(3)
26-509	Plastics Processing Theory	(3)
26-510	Plastics Processing Theory	(3)

In addition, the student must take 84-515 (Chemical Literature) (3 credits) and must register for Polymer Seminar (97-602) each semester.

The remaining formal course credits may be chosen from the following (other courses may be used with permission of the dissertation Committee):

97-511	Biopolymers	(2)
97-553	Organic Chemistry of Macromolecules	(2)
84-434-G	Colloid and Surface Chemistry and Its Environmental Applications	(3)
97-549	Physical Chemistry of Macromolecules I	(3)
97-550	Physical Chemistry of Macromolecules II	(3)
26-502	New Plastics Processing Techniques	(3)

26-504 Processing, Morphology, and Properties (3)
26-507 Plastics Industry Organization (3)
25-512 Plastics Foams (3)
26-513 New Plastics Materials (3)
26-516 Composite Materials (3)
26-518 Product Design (3)
26-521 Polymerization Engineering (3)
26-523 Material & Energy Balances in Plastics Processing (3)
26-531 Survey of Synthetic Fibers & Fiber Structures (3)
26-532 Adhesives and Adhesion (3)
26-533/4 Coatings Science and Technology (3)/(3)
26-535 Rubber (3)
26-536 Rheology in Polymer Processing (3)
26-537 Engineering Properties of Plastics (3)
26-543 Survey of Plastics Materials (3)
26-544 Survey of Plastics Processing (3)

Courses of Study (Department of Chemistry)

97-503 Advanced Polymer Science I *Blumstein* **(3-0)3**
Prerequisite: Permission of Instructor
Introduction to chain statistics and thermodynamics of macromolecular solutions, methods of study of molecular weight and chain conformation, and the properties of polymers in bulk including viscoelasticity and crystallinity.

97-504 Advanced Polymer Science II *Staff* **(3-0)3**
Prerequisite: Permission of Instructor
A study of the principles of condensation, free radical, ionic, coordination and ring-opening polymerization. The topics include the concepts of step-growth and chain-growth polymerization, the effect of polymerization techniques on reaction kinetics and molecular weight and molecular weight distribution, and the evaluation of reactivity ratios in copolymerization reactions.

97-505 Polymer Preparation and Characterization I *Staff* **(0-4)1**
Prerequisite: Permission of Instructor
A laboratory course designed to acquaint the graduate student with the techniques used in the synethsis and characterization of macromolecules.

97-506 Polymer Preparation and Characterization II *Staff* **(0-4)1**
Prerequisite: Permission of Instructor
An advanced laboratory in polymer science concerned with the instrumental study of macromolecules by utilization of osmometry, light scattering, gel permeation chromatography, vapor pressure osmometry, infrared spectroscopy, thermogravimetric analysis and differential thermal analysis.

97-511 Biopolymers *Sawan* **(3-0)3**
Prerequisite: Permission of Instructor
Conformation and configuration of vinyl polymers and polypeptides. Helix-coil transitions in proteins and polypeptides. Biological specificity and macromolecular structure. Synthesis of stereo-regular polypeptides. Structure and physical properties of nucleic acids. Relations of synthetic polymers to naturally occurring polymers.

97-512 Properties of Bulk Polymers *Clough* **(3-0)3**
Prerequisite: Permission of Instructor
Structure and properties of bulk polymers in the glassy, rubbery, and crystalline states. Topics covered include chain statistics, rubber elasticity, crystalline polymers, glass transition, segmental motion and viscoelasticity.

97-549 Physical Chemistry of Macromolecules I *Pyun, Clough* **(3-0)3**
Prerequisite: 97-503 or equivalent
Physical chemistry of polymers, including structure and conformation, chain statistics, molecular weight distributions and averages, polymerization kinetics and classical and statistical thermodynamics of polymer solutions.

97-550 Physical Chemistry of Macromolecules II *Blumstein, Pyun* **(3-0)3**
Prerequisite: 97-549 or equivalent
Optical and hydrodynamic properties of polymer solutions. Methods of determination of structural parameters, including light scattering, viscometry, and other techniques.

97-553 Organic Chemistry of Macromolecules *Salamone* **(3-0)3**
Prerequisite: 97-503, 504
An advanced study in polymer science concerned with the synthesis of macromolecules and their mechanisms of formation.

97-601 Polymer Science Seminar **(1-0)1**
Required of all Polymer Science graduate students
Presentation of current topics in polymer science by visiting scientists, faculty and graduate students.

97-651 Selected Topics in Polymer Science *Staff* **(3-0)3**
Prerequisite: Permission of Instructor
Advanced topics in various aspects of polymer science. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge in the field of macromolecules.

97-707 Graduate Research in Polymer Science *Staff* **(0-9)**
An independent investigation of a problem by the student in conference with a polymer science faculty adviser and approved by the Department Chairperson. A clear and systematic written presentation of the results is required.

97-751 Advanced Projects in Polymer Science *Staff* **(0-3)1**
Special projects undertaken by a student to expand knowledge in a specific field not necessarily related to the thesis. Content of project and hours assigned must be approved by the Department Chairman.

Candidacy for the Doctorate in Chemistry

To be admitted for candidacy for the doctorate, a student must:

1. complete a first year's core of recommended subjects and have a satisfactory record in undergraduate training, graduate seminar and collateral reading.
2. complete the course credit requirements.
3. pass the area examinations.
4. fulfill the language requirements.
5. secure the approval of his/her Advisory Committee and the Graduate Coordinator of the Department of Chemistry.

When these requirements have been fulfilled, the Graduate Coordinator of the Department of Chemistry notifies the Dean of the Graduate School in writing and recommends that the student be placed on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

Ph.D. — Option in Environmental Studies

An Interdisciplinary Program

This graduate program in Chemistry is designed to meet the need for Ph.D.'s who have experience in various areas of environmental research. The candidates in this program will have available to them courses and faculty not only in Chemistry, but also Physics, Biology, Civil Engineering and Chemical Engineering. The combination of faculty with a variety of research expertise give this program unique characteristics and affords the student the opportunity to perform practical interdisciplinary research. It is expected that most students will require at least four years beyond the Bachelor's and two years past the Master's degrees.

Entrance Requirements

The applicant will have an earned bachelor's degree in one of the following fields: Chemistry, Chemical or Civil Engineering, Biology, Environmental Sciences, Geology or Physics, with at least 24 credits in Chemistry. Students with fewer credits in Chemistry may remedy these deficiencies at the University, prior to matriculation in the program. Admission will be determined by committee based on grade point average and recommendations. The student who is accepted into the program will be required to take American Chemical Society Diagnostic Exams prior to the first

semester to determine if any deficiencies exist in the appropriate areas.

Program Outline

There are 27 courses credits (14 of which are required), and a minimum total of 45 credits. The difference is usually comprised mainly of research credits. After the first year of study the student must have a 3.2 cumulative average with no grade below a BC. In addition the student will register for departmental seminar each semester the student is in residence.

Course Offerings

Listed below are some of the elective courses which are currently being offered:

84-514 Advanced Analytical Chemistry	(3-0)3
84-519 Environmental Chemistry	(3-0)3
84-526 Chromatography	(3-0)3
84-560 Structural Analysis	(3-0)3
98-503 Radiation Biology	(3-0)3
14-561 Physical Chemical Treatment Processes	(3-0)3
18-527 Environmental Law	(3-0)3
81-510 Limnology	(3-0)3
84-585/6 Nuclear Chemistry	(3-0)3

Facilities

Most of the research laboratories are housed in the Olney and Olsen Buildings. Available for use by students: 60 and 100 MH_z NMRs, Infrared and UV-visible Spectro-photometers, Gas and Liquid Chromatographic instrumentation and Atomic Absorption Spectrophotometers. The Pinanski Energy Center houses our 5.5 MeV Van de Graaff Accelerator, 1 Megawatt research reactor and several radiochemistry laboratories.

Ph.D. — Option in Biochemistry

An Interdisciplinary Program

The Department of Biological Sciences and the Department of Chemistry have developed a program in Biochemistry leading to a Ph.D. in Chemistry. This program draws upon the special and diverse talents of both faculties, and provides students with both in-breadth class work and in-depth thesis research. Emphasis is on the application of modern techniques and concepts of physical and chemical science to the solution of problems of current interest in biology and medicine.

Requirements for Admission to the Program

In addition to the general requirements outlined by the Graduate

School, the student must have completed requirements for an acceptable B.S., B.A. or M.S. degree in Chemistry, Biology, or Biochemistry. Students with a Bachelor's or Master's degree in Biology will be expected to have completed two semesters each of general, organic, and Physical Chemistry, while those with a degree in Chemistry will be expected to have completed at least two semesters of an introductory Biology course. Deficiencies in undergraduate course work should be removed within the first year of residence.

Research

A. *Initiation of Research*

The dissertation research of each Ph.D. candidate may be initiated after one semester of residence. This research must be begun by the end of the first year in residence. The choice of research preceptor will be made by the student who should attempt to identify the area of his research interest and particular research group which may be suitable for pursuing his research goals.

B. *Advisory Committee*

After the student has chosen a research preceptor, an Advisory Committee will be appointed to monitor the progress of the student's research. The committee will be made up of at least three members, the student's adviser (as chairperson of the committee) and one each from the Departments of Chemistry and Biological Sciences. The Advisory Committee will also be responsible for monitoring qualifying and general examinations for the students.

Examinations

A. *Qualifying Examination for Biochemistry*

If the average letter grade for Biochemistry I and II is less than B, the student is required to pass an oral examination in Biochemistry administered by the student's Advisory Committee. Incoming students wishing to receive credit for an undergraduate biochemistry course may also be requested to pass this examination. A petition to take the examination may be made to the Biochemistry Program Curriculum Committee. Failure to achieve either the necessary letter grade average in Biochemistry I and II, or a passing grade on the qualifying exam will be reason for review of the candidate's status in the program. The student will be advised either to withdraw from the program or to take the examination again.

B. *General Examination*

The general examination is designed to evaluate the student's overall background, general development as a biochemist with special reference to current interest in literature, and preparedness as a scientist. The examination will consist of an oral presentation of an original research proposition on a topic other than that of the student's thesis work. The student will prepare an outline of his proposed research (to be distributed to the Advisory Committee at least a week before the examination) and will defend the arguments orally in front of the examination committee and other interested faculty members. Questions will not necessarily be limited to the area of the proposal. In the event of failure, the student may petition to retake the exam. This exam must be completed before the start of the third year in the program.

Admission to Candidacy for the Doctorate

To be admitted to candidacy for the doctorate, a student must:

1. Complete all required courses with necessary grade point average
2. Pass the General Examination and, if necessary, the qualifying examination
3. Fulfill the language requirement (as outlined by the Chemistry Department)
4. Secure approval of the research preceptor and the Biochemistry committee

When these requirements have been fulfilled, the Biochemistry Program Curriculum Committee will recommend that the graduate coordinator of the Department of Chemistry notify the dean of the Graduate School to place the student on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

DEPARTMENT OF MATHEMATICS AND COMPUTER SCIENCE

Department Chairperson: Alan W. Doerr, *Associate Professor;* B.S., Marist College; M.A., Hunter College.

Graduate Coordinators: Donald L. Ameen (Continuing Education), *Associate Professor;* B.S., Lowell Technological Institute; M.S., Cornell University.

Garfield C. Schmidt, *Associate Professor;* B.S., M.S., Kansas State University; Ph.D., University of New Hampshire.

Faculty

Indu M. Anand, *Assistant Professor;* Ph.D., New York University.

Shimshon Berkovits, *Associate Professor;* Ph.D., Northeastern University.

Pasquale Condo, *Associate Professor;* M.S., Lowell Technological Institute.

Thomas M. Costello, *Associate Professor;* Ph.D., University of Maryland.

Enrique Gonzalez-Velasco, *Assistant Professor;* Ph.D., Brown University.

Gerald Kaiser, *Associate Professor;* Ph.D., University of Wisconsin; Ph.D., University of Toronto.

Alan Kaplan, *Assistant Professor;* Ph.D., Syracuse University.

Kenneth M. Levasseur, *Assistant Professor;* Ph.D., University of Rhode Island.

Thomas F. McElligott, *Professor;* Ed.M., Boston University.

William F. Moloney, Jr., *Assistant Professor;* M.S., Lowell Technical Institute.

Joseph L. Neuringer, *Professor;* Ph.D., New York University.

Mary Beth Ruskai, *Assistant Professor;* Ph.D., University of Wisconsin.

Stanley L. Spiegel, *Assistant Professor;* Ph.D., Harvard University.

Charles A. Steele, *Instructor;* M.A., Boston College; M.A., Boston University; M.S.E.E., E.E., Northeastern University.

Virginia S. Taylor, *Associate Professor;* Ph.D., Boston College.

I. Jacob Weinberg, *Professor;* Ph.D., M.I.T.

Joyce W. Williams, *Assistant Professor;* Ph.D., University of Illinois.

Master of Science Degree Program

There are four options available in this program.

A. Applied Mathematics
B. Computer Science
C. Mathematics for Teachers
D. Statistics

Any student with a four year undergraduate degree from an accredited college or university and a satisfactory grade point average is eligible for admission to options B and C, but those interested in options A and D should possess a substantial background and ability in Mathematics. The aptitude part of the Graduate Record Examination is required for all options.

Applications for admission are due April 30 for the fall semester and November 30 for the spring, except for foreign students who must apply by March 15 and October 15 for the respective semester.

All programs consist of thirty credit hours approved by the Graduate Academic Policy Committee. Graduate course offerings from other departments and a maximum of 6 credit hours at the 400 level may be considered for inclusion in the program of study.

Courses will be offered on a regular basis in the late afternoon and early evening so that all programs may be completed on a part-time basis.

A. Applied Mathematics

This option is designed to provide the mathematical skills necessary to solve a variety of industrial, commercial, and engineering problems. A core program of two semesters of real analysis and one semester of complex analysis can be augmented with courses in probability, statistics, modern computing techniques and numerical mathematics, optimization theory, operations research, and computer science.

B. Computer Science

This option is designed for students with little formal education in computer science or mathematics. A demonstrated level of mathematical maturity equivalent to that outlined in 92-321, Discrete Structures I, in the University of Lowell catalogue, a knowledge of assembler language and PASCAL are prerequisites for the program. Students with no programming experience are strongly urged to spend a full year taking FORTRAN and/or other programming courses while completing the prerequisites before beginning the formal program.

The core program consists of Data Structures, Analysis of Algorithms, and Operating Systems. The remainder of the program is selected with the approval of the Graduate Academic Policy Committee from the graduate offerings in computer science, mathematics and statistics, and graduate offerings from other departments.

C. Mathematics for Teachers

This option is for primary and secondary school teachers. Applicants should have taken calculus through multivariate calculus, otherwise they may be required to complete certain undergraduate courses before becoming fully matriculated.

The program consists of six sequential credit hours in analysis (either 92-501, 502 or 92-511, 512), three in Algebra (92-521, 522, 821, 822), three in geometry (92-841, 843) and three in Applied Math or Computer Science. The remaining 15 are to be chosen from any of these areas.

Certificate in Mathematics

The department offers a five course program leading to a Certificate in Mathematics for those who, for a variety of reasons, wish to improve on their mathematical ability and skills. To obtain a certificate a student must take five upper level courses; at least three of these are to be selected from the following.

92-800 Survey of Analysis
92-801 Analysis
92-802 Survey of Mathematics
92-821 Linear Algebra I
92-841 Geometries I
92-843 Geometries II
92-871 Programming Languages I

Students enrolled in the Certificate Program are classified as Non-degree Students. At any time, a Non-Degree student can apply for a change to matriculated status. Such a request will be approved if and only if the applicant meets all the admission and retention standards of the Graduate School. Any certificate student admitted thus to matriculated status will be allowed to include in his/her M.S. program all coordinator-approved University of Lowell graduate courses which are pertinent and which are of sufficient grade quality. This will in no way reduce the number of credits transferrable to an M.S. program from outside the University.

D. Statistics

The statistics option prepares the student for employment as a statistical analyst in government or industry. Students obtain the broad background required for this type of work by pursuing a balance of probability plus theoretical and applied statistics. Deficiencies in one's mathematical background may be rectified while being enrolled in the program on a provisional basis.

A core of courses in mathematical statistics, applied methods, and stochastic processes will be augmented with a selection of courses approved by the Graduate Academic Policy Committee from the department's offerings in statistical sampling, multivariate analysis, regression and time series, distribution theory, and relevant course offerings from other departments.

Five Year B.S./M.S. Program

The department also has a five year B.S./M.S. program for outstanding undergraduates. See elsewhere in the undergraduate catalogue for details.

Courses of Study

A number of the following courses will be offered on a rotating basis as late afternoon or evening (Continuing Education) courses. The 800 level courses are for the teacher option only.

92-501,502 Real Analysis I, II **(3-0)3,(3-0)3**
Real and complex number systems. Set theory. Bolzano-Weierstrass and Heine-Borel theorems. Sequences and series. Continuity. Differentiation. Riemann integration. Sequences and series of functions. Functions of several variables. Measure and integration.

92-503,504 Applied Functional Analysis I, II **(3-0)3,(3-0)3**
Vector spaces, metric spaces, normed spaces, Banach and Hilbert Spaces. Applications to integral and differential equations and approximation theory. Spectral theory of linear operators, compact operators, and unbounded linear operators. Applicants to quantum mechanics - states, observables, Heisenberg Uncertainty Principle, Schrodinger equation, and Hamilton operator.

92-511,512 Complex Analysis I, II **(3-0)3,(3-0)3**
Complex numbers and their geometric representation, linear functions, power series, analytic functions, and conformal mapping, elementary functions, complex integration and integral theorems. Series and the expansion of analytic functions in series, singularities, single-valued functions, entire functions, metamorphic functions, periodic functions.

92-521,522 Algebraic Structures I, II **(3-0)3,(3-0)3**
Properties of rings, groups, and modules in the framework of categorical algebra. Divisibility theory in integral domains. Linear and multilinear algebra. Field extensions and Galois theory. Homology groups.

92-537,538 Vector and Tensor Analysis I, II **(3-0)3,(3-0)3**
The geometry of curves and surfaces, Serre-Frenet formulas, intrinsic equations of a curve, first and second fundamental forms of a surface, divergence, curl, and gradient. Tensor algebra, covariant and contravariant tensors, covariant differentiation and parallel displacement. Applications to differential geometry and selected topics.

92-539,540 Differential Forms and Their Applications I, II (3-0)3,(3-0)3

Vector calculus; curves and surfaces; differential forms as multilinear maps; the gradient, curl, and divergence as exterior derivatives; the general Stokes' Theorem; applications to electrodynamics and thermodynamics.

92-543,544 Ordinary Differential Equations I, II (3-0)3,(3-0)3

Existence and uniqueness theorems. Linear systems, Asymptotic behavior. Oscillation and comparison theorems. Plane autonomous systems. Non-linear systems. Stability theory and perturbation theory. Topics in optimal control theory. Other topics of current interest.

95-545,546 Partial Differential Equations I, II (3-0)3,(3-0)

First and second order partial differential equations, transformation theory in the plane and space. Applications to mathematical physics. Classification and methods of solution. Properties of solutions of equations with initial and boundary conditions. Existence and uniqueness theorems.

92-547 Integral Equations (3-0)3

Exact, iterative, and numerical techniques for the solution of linear Volterra and Fredholm integral equations, theorems for general operators. Symmetric kernels, orthogonal system of functions, and the Hilbert-Schmidt theorem. Relation of integral equations to differential equations, applications of the Rayleigh-Ritz, Galerkin and variation-iteration techniques to the solutions of eigenvalue-eigenfunction problems occurring in mathematical physics and engineering.

92-551 Calculus of Variations (3-0)3

The first variational problem: necessary conditions. Euler's equation. Generalization to several dependent and independent variables. Constraints and Lagrange multipliers. Application to dynamics and elasticity. Hamilton equations. Sturm-Liouville problems, direct methods. Rayleigh-Ritz method.

92-553 Systems Simulation and Modeling (3-0)3

Prerequisite: knowledge of Fortran and Assembly language

Procedures in model construction and computerized simulation, modeling tools and techniques, model conceptualization and implementation, selected applications of simulation.

92-559 Artificial Intelligence (3-0)3

Prerequisite: Assembly language

An examination of the techniques and procedures involved in the production of intellectually behaving computer programs. The student will learn to plan and construct programs which "learn" from their own experience. The aim of the course is to enable students to understand what a computer program can do to analyze information, develop strategies and make decisions.

92-560 Data Structures (3-0)3

Prerequisite: some mathematical maturity and PASCAL

Basic concepts of data. Linear lists, strings, arrays and orthogonal lists. Trees and graphs. Storage systems and structures. Storage allocation and collection. Multilinked structures. Symbol tables searching and sorting (ordering) techniques.

92-561 Approximation Theory **(3-0)3**
Approximation techniques for functions. Interpolation, rational approximation, orthogonal functions.

92-563 Numerical Solution of Differential Equations **(3-0)3**
Solution of non-linear equations. Interpolation. Numerical differentiation and integration. Initial value problems. Boundary value problems-introduction. Parabolic differential equations-introduction.

92-564 Numerical Algebra and Approximation Theory **(3-0)3**
Solution of linear systems. Eigenvalue, eigenvector problem. Fast Fourier Transform. Introduction to finite elements. Least squares. Splines, Chebychev approximation.

92-565 Formal Languages **(3-0)3**
Prerequisite: PASCAL
This course will study the formal or abstract properties of (computer) languages and of acceptors/recognizers for valid expressions in the syntax of the language. Topics to be covered will include: the Chomsky hierarchy of languages, Finite State Machines: their basic properties/results and as acceptors for Regular Expressions. Two-way Acceptors and Automata, Pushdown Automata: acceptors for Context Free Languages and grammars for Pushdown Automata. Context Free Grammars. Tranformations on grammars and canonical forms for grammars. Syntax Analysis: top-down, bottom-up and precedence analysis. Parsing. Turing Machines.

92-566 Theory of Computation **(3-0)3**
Prerequisite: PASCAL
Models of computation. Turing machines and Turing-computable functions. Other models of computation. The Church-Turing thesis. Universal machines. Recursive functions, primitive recursive and partial recursive functions. Simulation of various computations. Recursive and recursively enumerable sets. Unsolvable problems: Computable versus non-computable functions. Halting problem, equivalence problem, word problems, etc. Other topics as time and interest permit.

92-567 Systems Programming **(3-0)3**
Prerequisite: Assembler Language and Data Structures
Systems software as concerned with language processors: assemblers, macro processors, compilers. Review of relevant data structures and utilities. Review of relevant issues in language theory and design: block structure, symbol binding, etc. Assemblers. Compilation: lexical, syntactic and semantic analysis. Code generation. Optimization. Parsers and parsing techniques.

92-568 Operating Systems **(3-0)3**
Prerequisites: Assembler Language and Data Structures
Models of operating systems: resource manager, process, hierarchical model and extended machine. Systems structure: operating systems structure, software/hardware tradeoffs. Processes: parallelism/concurrency, deadlock, mutual exclusion. Process synchronization. Control: scheduling, interrupts, priority. Multi-programming. Memory management: paging, segmentation, virtual memory. Name management. Resource allocation: memory, CPU scheduling, queueing, etc. File structures. Protection.

92-569 Compiler Construction Techniques (3-0)3
Prerequisites: PASCAL and Data Structures
Typical compiler organization is studied including symbol tables, various types of scans, object code generation, error diagnostics, and optimization techniques. Segments of a classroom compiler are written by students.

92-570 Data Communications (3-0)3
Prerequisites: PASCAL and Data Structures
Analysis and use of remote computing systems including time-sharing remote batch and real-time systems. Design characteristics, applications, data communication, economics and management of such systems.

92-571,572 Optimization and Mathematical Programming I, II (3-0)3,(3-0)3
Linear programming, simplex methods, dual problem, transportation problem, assignment problem, sensitivity analysis, introductory integer programming and application of each of the techniques. Second semester covers integer programming network flows and analysis, classical nonlinear optimization. Lagrange multipliers. Kuhn-Tucker conditions, nonlinear programming and some calculus of variations.

92-574 Data Base Management (3-0)3
Prerequisite: Permission of program coordinator
An introduction to Data Base software. The structures and examples of existing systems. The computer facility will be used to illustrate some of the concepts of the software.

92-575 Analysis of Algorithms (3-0)3
Prerequisite: Data Structures
Basic steps in developing an algorithm, correctness, algorithm design techniques such as hill climbing, subgoals, heuristics, backtracking, branch and bound, recursion, sorting and searching, paging, parallelism. Algorithm and program correctness: measures of algorithm efficiency, complexity and overall effectiveness.

92-578 Programming Language II (3-0)3
Prerequisite: A higher level language
An intensive examination of the COBOL language with a focus on structured programming techniques, including an examination of the COBOL DATA and PROCEDURE divisions. Emphasis will be placed on sequential and ransom access files, the COBOL procedure verbs, and the SORT/MERGE and REPORT WRITER modules.

92-582 Regression and Time Series (3-0)3
Prerequisite: Permission of the Instructor
The method of least squares as applied to various types of regression, including multilinear, polynomial, and exponential. Time series, estimation, smoothing, forecasting. Trends and seasonal effects.

92-584 Stochastic Processes (3-0)3
Prerequisite: 92-307 or 92-587
Stationary and independent increments, Markov chains and processes, recurrence and absorption, random walks, poisson processes, queueing theory, and martingales.

92-587,588 Mathematical Statistics I, II (3-0)3,(3-0)3
Random variables, densities, joint and conditional distributions, expecta-

tion, variance, estimation, sufficiency and completeness, hypothesis testing, limiting distributions.

92-651,652 Selected Topics I, II **(3-0)3,(3-0)3**
Advanced topics in various fields of mathematics. Content may vary from year to year. Permission of graduate coordinator required.

92-800 Survey of Analysis **(3-0)3**
Includes topics in Analysis and/or Mathematics in general. (This course is specifically designed for the certificate program. Its contents will vary with student needs.)

92-802 Survey of Mathematics **(3-0)3**
Continuation of 92-800.

92-801 Analysis **(3-0)3**
Calculus from an advanced viewpoint. The course is designed to provide teachers with the background necessary to teach Advanced Placement Mathematics. (This course is specifically designed for the teacher option.)

92-813 Theory of Numbers **(3-0)3**
Study of primes, congruences, number-theoretic functions, Dirichlet series, quadratic forms and quadratic number fields. Additional topics as time permits.

92-821,822 Linear Algebra I, II **(3-0)3,(3-0)3**
Mathematical induction, the properties of sets; Mappings and mathematical logic, vectors in R^n; vector spaces, matrices; linear mappings; the effect of a change of basis; the matrix associated with a linear map; applications. Scalar products and orthogonality; matrices and bilinear maps; polynomials and matrices; triangulation of matrices and linear maps; the Spectral Theorem; matrix analysis; applications.

92-841 Geometries I **(3-0)3**
Euclid's and Hilberts axioms; non-Euclidean geometries, the space concept and an introduction to basic topological concepts.

92-843 Geometries II **(3-0)3**
A continuation of Geometries I; synthetic and analytic treatment of projective transformations, duality, conics poles, involution.

92-871 Programming Languages I **(3-0)3**
An introduction to the formal concepts of programming languages including specification of syntax and semantics. Examination of programming languages (FORTRAN, COBOL, BASIC APL) The University's computer will be used for processing of practice problems.

DEPARTMENT OF PHYSICS AND APPLIED PHYSICS

Department Chairperson: Zoltan Fried, *Professor;* B.S., Brooklyn College; Ph.D., Brandeis University.

Graduate Coordinator: Kunnat Sebastian, *Professor;* B.S., M.S., Kerala University; Ph.D., University of Maryland.

Faculty

Albert Altman, *Professor;* B.S., Brooklyn College; M.S., Ph.D., University of Maryland.

Adolph Baker, *Professor;* B.A., City College of New York; B.M.E., Polytechnic Institute of Brooklyn; M.S., in Ed., City College of New York; M.S., New York University; Ph.D., Brandeis University.

Leon E. Beghian, *Professor;* B.A., D.Phil., University of Oxford.

Klaus Bibl, *Research Professor;* Ph.D., University of Freiburg, Germany.

Gus Couchell, *Professor;* B.S., M.S., North Carolina State University; Ph.D., Columbia University.

James J. Egan, *Associate Professor;* B.A., Thomas More College; M.S., Ph.D., University of Kentucky.

Padmanabh Harihar, *Associate Professor;* B.Sc., R. Ruia College; M.Sc., Wilson College, India; Ph.D., Columbia University.

Lloyd C. Kannenberg, *Professor;* B.S., Massachusetts Institute of Technology; M.S., University of Florida; Ph.D., Northeastern University.

Gunter H.R. Kegel, *Professor;* B.Fis., Universidade de Brasil; Ph.D., Massachusetts Institute of Technology.

Suresh C. Mathur, *Professor and Director of the Computer Center;* B.Sc., University of Lucknow; Ph.D., University of Texas.

Roger D. McLeod, *Associate Professor;* B.A., Bowdoin College, M.S., Lowell Technological Institute.

Arthur Mittler, *Associate Professor;* B.A., Drew University; M.S., Ph.D., University of Kentucky.

Harry E. Moses, *Research Professor;* B.S., M.S., University of Michigan; Ph.D., University of Columbia.

David J. Pullen, *Professor;* B.Sc., University of London; D.Phil., University of Oxford.

Walter A. Schier, *Professor;* B.S., Saint Procopius College; Ph.D., University of Notre Dame.

Eric Sheldon, *Professor;* B.Sc., (Gen) and B.Sc., (Special Honors), D.Sc., D.Phil., University of London.

Richard W. Stimets, *Associate Professor;* B.S., Ph.D., Massachusetts Institute of Technology.

Ye Yung Teng, *Associate Professor;* B.S., National Taiwan University, China; M.S., Ph.D., University of Maryland.

Jerry Waldman, *Associate Professor;* (on leave); B.A., M.A., Columbia University; Ph.D., Massachusetts Institute of Technology.

Martin Wilner, *Professor;* B.S., Rensselaer Polytechnic Institute; M.S., Yale University; Ph.D., Massachusetts Institute of Technology.

Chuen Wong, *Assistant Professor;* Diploma of Science, Chung Chi College, Hong Kong; Ph.D., Case Western Reserve University.

PHYSICS AND APPLIED PHYSICS

Research Programs

Members of the Department are engaged in research programs in the following areas in which opportunities for advanced degree thesis research are offered: Theoretical and Experimental Nuclear

Physics, Theoretical and Experimental Solid State Physics, Laser Physics, Optics, Theory of Elementary Particles, Quantum Field Theory, Atomic Physics, Relativity, Atmospheric Physics, History of Physics, Biophysics, Nuclear, Solar and Geothermal Energy, Computational Physics, Applied Mechanics and Radiological Sciences.

Research facilities at the Nuclear Center include a 5.5 MeV Van de Graaff accelerator, a one-megawatt nuclear reactor, and an HP 2100 32K computer. The Solid State and Laser Physics Laboratory contains a 10-tesla superconducting magnet, a Fourier transform spectrometer, a scanning monochromator, and infrared and far infrared lasers. The University has a Cyber 71 computer available for both batch and time-shared usage.

Entering Graduate Students

Every entering graduate student is assigned a departmental adviser who will advise on programs of study and other academic requirements, serve as registration officer, help the student to become acquainted with research opportunities in the Department, and assist in selecting a thesis supervisor.

Entering graduate students are expected to have a sound background in intermediate level mechanics, electricity and magnetism, thermodynamics, statistical mechanics and modern physics. Any student found deficient in any of these areas may be required to take appropriate courses to remove that deficiency.

Master of Science Degree Program

The Master's program in physics provides an opportunity for advanced study and research in most of the areas mentioned above. The Master's Program in Radiological Sciences is described elsewhere in the catalogue.

Course Requirements

Thirty credit hours are required for the M.S. Of these, a minimum of 6 credits and a maximum of 12 credits may be for thesis or, if a project is approved by the department in place of M.S. thesis, then a maximum of 3 credits will be allowed.

A candidate for the M.S. degree electing to specialize in a particular area of applied physics will be required to complete a sequence of courses no later than the end of the first year of study. These courses, listed below, are designed by the Department to develop skills in the chosen specialty.

95-505,506	Mathematical Methods of Physics	(4-0)	(4-0)8
95-511	Classical Mechanics		(3-0)3
95-557	Electromagnetic Theory I		(4-0)4

In addition, the student's adviser must be assured that the student has attained an appropriate level of proficiency in all three of these topics.

Electives may be any course chosen from the list of physics courses acceptable for graduate credit, but not more than 3 credits may be for seminar or special topics courses. Some graduate courses offered by other departments are acceptable for graduate credits in physics, but only with the approval of the Physics Department.

Thesis or Project

After obtaining a research supervisor, each student must submit to the Department for its approval two copies of a typewritten proposal, which is to be a brief description of the problem to be solved for the thesis, and a proposal or a description of the project. This proposal must bear the written approval of the member or associate of the graduate physics faculty who has agreed to supervise the work. After completing the work, the student will submit three copies of a typewritten dissertation based on it to the Department. The student will then have to pass an oral examination administered by a committee of members of the Department, including his research supervisor, based on, but not necessarily restricted to, the subject of the dissertation. A student who submits an M.S. project in place of a thesis will be examined also on the subjects which all physics M.S. candidates are expected to know. (These are expected to be the subjects covered in the recommended M.S. course sequence.)

Language Requirements

There are no foreign language requirements for the Master of Science degree in Physics.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM
THE PHYSICS CONCENTRATION

Objectives

The degree of Doctor of Philosophy in Physics signifies an advanced competence in the various areas of physics and also recognizes a significant and original contribution to physical knowledge. To achieve this the doctoral program is designed to provide the graduate student with the training necessary for conducting independent research at a professional level. Doctoral research may be carried out in Theoretical and Experimental Nuclear Physics, Theoretical and Experimental Solid State Physics, Laser Phys-

ics, Optics Theory of Elementary Particles, Quantum Field Theory, Atomic Physics, Relativity, Atmospheric Physics and History of Physics.

Course Requirements
At least 60 credit hours are required for the Ph.D., of which at least 13 credits and at most 24 may be thesis research (95-701,702). However, credits in 95-701, 702 accepted in partial fulfillment of the M.S. requirement may not be accepted for the Ph.D. requirement.

The following courses are required:

95-505,506	Mathematical Methods of Physics	(4-0)	(4-0)8
95-511	Classical Mechanics		(3-0)3
95-515,516	Quantum Mechanics	(3-0)	(3-0)6
95-557,558	Electromagnetic Theory	(4-0)	(4-0)8
95-517	Advanced Quantum Mechanics I		(3-0)3
	or		
95-518	Advanced Quantum Mechanics II		(3-0)3

Electives may be chosen from the list of courses acceptable for graduate credit in physics, but explicit Department approval is required for graduate credit of 95-461, Topics in Nuclear Physics, and 95-472, Solid State Physics. Some graduate courses offered by other departments are acceptable for graduate credit in physics, but only with the approval of this Department.

Colloquia
All full-time students are required to attend Department colloquia.

Language Requirements
A demonstration of proficiency adequate for reading technical articles on physics (level two) in French, German, or Russian.

Other Skills
Either (a) a demonstration of reading proficiency (level two) in a foreign language from among French, German, or Russian in addition to that used for the language requirement, or (b) a demonstration of proficiency in computer programming, which may be validated by achieving a grade of B or higher in 90-361, Digital Computer Programming, or 80-397, Computer Programming and Applications I, or by demonstrating equivalent competence to the Physics Department.

Comprehensive Examination
Ph.D. candidates in the physics concentration are expected to take

the Ph.D. comprehensive examination in their first year. The written part of the examination covers Classical mechanics, Electricity and Magnetism, Quantum Mechanics and Modern Physics at the undergraduate level. If the student passes the written part, an oral examination is given normally one year later. It will be based on Advanced Projects (95-751/2 or their equivalents) and the graduate level courses taken in the first year.

Thesis Requirements
A thesis proposal must be submitted, according to the procedures outlined in the Master of Science program. A student may not register for 95-701, Graduate Research, until the Ph.D. comprehensive examination has been passed and the thesis proposal is approved. Registration for 95-711 and Research may begin sooner. The thesis is to be based on original research performed under the supervision of a member of the graduate faculty holding an earned Ph.D. degree, and written to conform to the requirements of the Graduate School. Four eligible copies of a typewritten original must be submitted to the Department. Following this, the student must pass an oral examination conducted by the thesis committee, based on, but not necessarily limited to thesis work. If a student wishes to do a thesis under the supervision of a member of the graduate faculty of another department or of the University of Lowell Research Foundation, consent of the Physics Department must be obtained.

THE APPLIED PHYSICS CONCENTRATION

General Description
The Applied Physics Ph.D. program offered by the Department of Physics and Applied Physics is organized jointly with the Department of Energy Engineering and the Department of Mechanical Engineering. It is designed to develop advanced competence in physics and to provide professional training in engineering. Students in the Applied Physics concentration may select a program of study and research in one of the following four areas:

1. Physics/Energy Engineering
   (a) Fission Option
   (b) Fusion/Plasma Option
   (c) Solar Energy Option
   (d) Geothermal Option
2. Physics/Applied Mechanics
3. Physics/Computation
4. Physics/Radiological Sciences.

Areas 1 and 2 are interdisciplinary programs with the departments of Energy Engineering and Mechanical Engineering respectively. Area 3, Physics/Computation involves the formulation, codification, simulation and solution of complex problems in physical systems using modern computers. Area 4 represents an extension of our M.S. program in Radiological Sciences and Protection.

Course Requirements

At least 60 credit hours are required for the Ph.D. of which at least 15 credits, and at most 24, may be thesis research. However, thesis credits accepted in partial fulfillment of the M.S. requirement may not be accepted for the Ph.D. requirement.

General Required Courses

(a) Demonstration of proficiency in the following courses:

95-513 (A)	Classical Mechanics
95-553/4(A)	Electricity and Magnetism I/II
95-535/6(A)	Quantum Mechanics I/II
95-505/6	Mathematical Methods of Physics I/II
	or
24-525/6	Numerical Methods of Reactor Analysis

(b) Six or eight credits from among the following options, or their equivalents, as appropriate for each particular area of concentration.

95-511	Classical Mechanics
95-522	Statistical Mechanics and Thermodynamics
95-515/6	Quantum Mechanics I/II
95-517/8	Advanced Quantum Mechanics I/II
95-557/8	Electromagnetic Theory I/II

(c) 95-751/2 Six credits of Advanced Projects in Physics or their equivalents in the department appropriate to the student's chosen field of concentration. This will be waived for students already having a Master's thesis.

(d) At least seven further courses from among the Physics, Energy Engineering and the Mechanical Engineering offerings at the graduate level. These seven courses should include the following required courses appropriate to each option.

Fission Energy Option (See Energy Engineering)

Fusion and Solar Energy Options (See Energy Engineering)

Geothermal Option (See Energy Engineering)

Applied Mechanics Option
At least two graduate courses from the Mechanical Engineering Department to be determined by the student's thesis and academic advisors.

Computational Physics Option
Students choosing this option must take the following courses:
92-563/4 Adv. Numerical Analysis I/II
92-871 Programming Languages
In addition they may also take a graduate course in computational physics which is yet to be developed.

Radiological Sciences Option
In addition to the general required courses, the students choosing this option must take seven courses from the following:
98-505 Radiation Dosimetry
98-507 Radiation Dosimetry Lab
98-532 Intro. Nuclear Rad. Shielding
98-534 Intro. Nuclear Rad. Shielding Lab
95-561/2 Nuclear Physics I/II
24-525 Numerical Methods
24-526 Adv. Engineering Math.

Language Requirement
The language requirement is the same as for the Physics Concentration.

Other Skills
This is the same as for the Physics Concentration.

Colloquia
Attendance at Department Colloquia/Seminars is required.

Comprehensive Examination
This examination is the same as the one given to the students of Physics Concentration. But the Ph.D. candidates in the Applied Physics Concentration normally take this examination in their second year.

Thesis Requirements
This is the same as for the Physics Concentration. Depending on the area of concentration, the student chooses a thesis advisor from the graduate faculty of Physics, Radiological Science, Energy Engineering or Mechanical Engineering.

The courses whose numbers are followed by the letter 'A' are intended only for graduate students in the Applied Physics Concentration.

95-513(A) Mechanics **(4-0)4**
Prerequisite: 92-208
Kinematics of a single particle, analysis of Newton's laws of motion, mechanics of a single particle in one and in more than one dimension, conservative and non-conservative forces, the linear oscillator, forced oscillations and resonance, central force motion, kinematics and elastic collisions in two particle systems, mechanics of particles, generalized coordinates, Lagrange's equations, the Hamiltonian function.

95-535(A) Introductory Quantum Mechanics I **(3-0)3**
Prerequisite: 95-210
De Broglie waves, the Schroedinger equation, wave functions, wave packets, Heisenberg uncertainty principle, expectation values, particle in a box, the simple harmonic oscillator, free particles, step barrier, barrier penetration, square well potential.

95-536(A) Introductory Quantum Mechanics II **(3-0)3**
Prerequisite: 95-335
The three dimensional Schroedinger equation, the deuteron nucleus, angular momentum, spin, the hydrogen atom, spin-orbit interaction, Zeeman effect, Pauli exclusion principle, atomic structure, spectroscopic nomenclature, and molecular structure.

95-553(A) Electromagnetism I **(3-0)3**
Prerequisite: 92-208, 95-210
The theory of electromagnetic fields using vector analysis and Maxwell's equations; static electric and magnetic fields in conductors and dielectrics, scalar and vector potentials, solutions to Laplace's equation, image charge problems, and energy density problems.

95-554(A) Electromagnetism II **(3-0)3**
Prerequisite: 95-353
Time-varying electromagnetic fields, ferromagnetic materials, propagation of plane waves in conductors and dielectrics, Snell's law, Fresnel equations, polarization, and radiation from accelerated charges and antennas.

95-421G Statistical Thermodynamics *Staff* **(4-0)4**
Prerequisite: Permission of Instructor
An integrated study of thermodynamics and statistical mechanics: review of the experimental foundations and historical development of classical thermodynamics; probability and statistical methods of studying macroscopic systems; atomic basis of the laws of thermodynamics and microscopic definitions of thermodynamic quantities using the method of ensembles; entropy and related quantities; TdS equations, Maxwell relations, equations of state and applications; canonical and grand canonical ensembles; phase transitions, quantum statistics; applications to radiation, magnetism, specific heats.

95-461G Topics in Nuclear Physics *Staff* **(3-0)3**
Prerequisite: Permission of Instructor
Not for graduate credit without explicit Department approval. This course is designed to familiarize the student with a few research areas in the field of nuclear physics. The topics selected will be covered in depth; they may vary from year to year, and they will be chosen from the following: Nuclear consitution, fundamentals of interaction forces, liquid drop model and stability energetics; cross sections, passage of ionizing radiations through matter, radioactive decay, alpha-decay, beta-decay and electron capture, gamma-decay and internal conversion, nuclear reaction systematics, fission and fusion, models and nuclear structure.

95-472G Solid State Physics *Staff* **(3-0)3**
Prerequisite: Permission of Instructor
Not for graduate credit without explicit Department approval. Crystal structures, X-ray and neutron diffraction. Lattice vibrations. The free electron and band models of metals. Semiconductors and applications. Dielectric and optical properties of solids. Magnetism. Superconductivity.

95-505,506 Mathematical Methods of Physics *Staff* **(4-0) (4-0)8**
Prerequisite: Permission of Instructor
Vector and Cartesian tensor analysis; matrices and determinants; partial differential equations, boundary value problems and special functions. Numerical analysis and applications: theory of analytic functions; Green's functions.

95-507 High-Energy Physics *Staff* **(3-0)3**
Prerequisite: 95-516
A survey designed for the nonspecialist. Elements of relativistic scattering theory, the quantum numbers and conservation laws of high-energy physics, strong and weak interactions, dispersion relations. Regge poles and unitary symmetry.

95-511 Classical Mechanics *Staff* **(3-0)3**
Prerequisite: Permission of Instructor
Lagrangian formulation (including Lagrange multipliers), the Kepler problem and Rutherford scattering; rotating coordinate systems and rigid body motion; small oscillations and stability problems; Hamiltonian formulation.

95-515,516 Quantum Mechanics *Staff* **(3-0) (3-0)6**
Prerequisite: 95-511 concurrently
Wave packets and free particle motion, the wave function and the Schrodinger equation, the linear harmonic oscillator, the WKB approximation, central forces and angular momentum, spin, and time-dependent and independent perturbation theory. Scattering theory.

95-517,518 Advanced Quantum Mechanics *Staff* **(3-0) (3-0)6**
Prerequisite: 95-516
The formal theory of scattering; Klein-Gordon and Dirac equations and simple applications; quantum theory of radiation. Symmetry principles and elements of group theory; introduction to many-body theory; Hartree-Fock self-consistent calculations and their applications to atomic, solid state, and nuclear physics.

95-522 Statistical Mechanics *Staff* **(3-0)3**
Prerequisite: Permission of Instructor
The classical statistical mechanics of Gibbs and Darwin-Fowler, the quan-

tum tatistical mechanics of Fermi-Dirac and Bose-Einstein, and applications to thermodynamics, solid-state physics, and nuclear physics.

95-557,558 Electromagnetic Theory *Staff* **(4-0) (4-0)8**
Prerequisite: 95-505,506 concurrently
and Permission of Instructor
Electrostatics and magnetostatics with special attention to boundary value problems. Quasistatic fields and displacement currents. Maxwell's equations, the Special Theory of Relativity, Waveguides, Mie scattering, radiation from an accelerated charge; plasma physics.

95-560 Applied Quantum Mechanics *Staff* **(3-0)3**
Prerequisite: 95-515,516
Relativistic Dirac equation of the electron and its simple applications. Symmetry principles in quantum mechanics and elements of group theory. Introduction to many body theory. Hartree-Fock self-consistent calculations, and their applications to the theory of many electron atoms, and the nuclei of atoms. Emission and absorption of radiation by quantum systems such as atoms and nuclei. Widths and intensities of spectral lines. Selection rules. Electric and magnetic multipole moments of nuclei and e.m. transition probabilities for nuclei.

95-561,562 Nuclear Physics *Staff* **(3-0) (3-0)6**
Prerequisite: Permission of Instructor
Stationary states of nuclei, nuclear charge radius, mass, moments, parity, and statistics; theory of alpha, beta, and gamma decay; fission reactions induced by charged particles, gamma rays, and neutrons; nuclear forces and nuclear models; and fast neutron physics.

95-573 Advanced Theory of Solids I *Staff* **(3-0)3**
Prerequisite: Permission of Instructor and 95-516
Lattice vibrations and their interactions with X-rays, neutrons and light. The band model of solids and energy band calculations. The Fermi surface. Transport and optical properties in metals and semiconductors.

95-574 Advanced Theory of Solids II *Staff* **(3-0)3**
Prerequisite: 95-573
Magnetism and magnetic resonance. Superconductivity. Many body theory and its applications. Collective excitations. Green function techniques in solid state physics.

95-575,576 Neutral Particle Transport *Beghian* **(3-0) (3-0)6**
Prerequisite: Permission of Instructor
Boltzmann and integral transport equations. Spherical harmonic and variational methods. Corrections to diffusion theory. Special methods of solving transport equations. Adjoint functions. Applications.

95-581,582 Theory of Noise and Random Processes *Korff* **(3-0) (3-0)6**
Prerequisite: 95-505, 506
95-521,522 (May be taken concurrently)
Probabilities. Statistical analysis of random processes. Ensemble theory. Signals and noise in nonlinear systems. Information theory. Normally distributed random processes. Langevin, Fokker-Planck and Boltzmann equations. Thermal, shot and impulse noise. Linear measurements, prediction, and optimum filtering. A strong background in applied mathematics required. Some knowledge of AC circuit theory and electronics would also be useful.

95-583,584 General Theory of Relativity *Kannenberg* **(3-0) (3-0)6**
Prerequisite: Knowledge of Special Relativity including Tensor Notation
Review of Newtonian gravitational theory and special relativity. The weak and strong principles of equivalence. Tensor analysis in Riemann spaces. Einstein's equations for the gravitational field. Classic tests of Einstein's theory; spherically symmetric solutions. Gravitational field theory and the canonical analysis of general relativity.

95-593,594 Graduate Laboratory *Staff* **(0-9) (0-9)6**
Prerequisite: Permission of Instructor
A laboratory course designed to acquaint the graduate student with the methods and techniques of modern experimental physics.

95-601 Seminar in Physics **(1-0) (1-0)2**

95-603 Seminar in Nuclear Physics **(1-0) (1-0)2**

95-605 Seminar in Solid State Physics *Staff* **(1-0) (1-0)2**
Individual presentations by students and the instructor of advanced topics: original research or journal articles. Given only when the demand is sufficient.

95-651 Selected Topics in Physics **(3-0) (3-0)6**

95-653 Selected Topics in Nuclear Physics **(3-0) (3-0)6**

95-655 Selected Topics in Solid State Physics **(3-0) (3-0)6**

95-657 Selected Topics in Theoretical Physics *Staff* **(3-0) (3-0)6**
Recent advances, more advanced topics, not covered in the regular courses in these topics. Given only when the demand is sufficient. Subject matter varies, depending on the interests of the instructor and the needs of the students. Subject matter varies sufficiently that these courses may be taken twice for credit without repeating topics.

95-701 Graduate Research in Physics *Staff* **(0-9) (0-9)6**
Departmental approval of a written thesis proposal
Research for M.S. or Ph.D. thesis.

95-711,712 Special Problems in Physics *Staff* **(0-9) (0-9)6**
Prerequisite: Permission of Instructor
Reading in preparation for research (in subjects not offered in courses at the time the student wishes to study them), or research not for thesis. If results of the research are subsequently incorporated in a thesis, credits earned in 711-712 may be used to satisfy credit requirements in 701-702. If results are incorporated in an M.S. project, not more than 3 credits are allowed.

95-751,752 Advanced Projects in Physics *Staff* **(0-3) (0-3)2**
Prerequisite: Permission of Instructor
Independent reading or research not for thesis.

80-586 Semiconductors *Staff* **(3-0)3**
Transport and optical properties of semiconductors. Statistics, collision mechanisms, and band structure. Hot electrons. High magnetic field phenomena. Devices: Junctions and transistors. Gunn oscillators; semiconductor lasers.

RADIOLOGICAL SCIENCES AND PROTECTION (DEPARTMENT OF PHYSICS)

Graduate Coordinator: Edward L. Alexander, *Professor;* B.S., M.S., University of Maine; Ph.D., Vanderbilt University.

Faculty

George E. Chabot, *Adjunct Assistant Professor;* A.B., Harvard University; M.S., Harvard School of Public Health, (C.H.P.).

Jesse Y. Harris, *Professor;* B.S., M.S., Ph.D., Rutgers-The State University.

Anthony Liuzzi, *Professor;* B.S., Rensselaer Polytechnic Institute; M.S., Ph.D., New York University, (C.H.P.).

Kenneth W. Skrable, *Professor;* B.S., Moravian College; M.S., Vanderbilt University; Ph.D., Rutgers-The State University, (C.H.P.).

Doctor of Philosophy Degree Program —

See Applied Physics concentration in this catalogue.

Master of Science Degree Program

With the increasing uses of radiation and radioactive materials and the projected increase in the utilization of nuclear power, there will be a growing need for research in Radiological Sciences and Protection. The excellent facilities, equipment and supporting staff available at the University of Lowell Energy Center and faculty in the Radiological Sciences Program and in other allied departments give students at the University a unique opportunity to make significant contributions to research in the field.

The master of science degree program in Radiological Sciences and Protection is interdisciplinary in nature and should be attractive to engineering students and students in the biological and physical sciences. The program is complementary to the master of science degree program in Environmental Studies, enabling students at the University to pursue careers in all the major areas of environmental protection.

Students are given the opportunity to select programs which respond to the growing manpower needs arising from the increasing use of nuclear energy sources and the increasing uses of radiation and radioactive materials in industry, government, and medicine. For example, the current energy crisis which has resulted from the high level of concern exhibited today regarding the environment has created a critical shortage of professionals needed to perform evaluations of the environmental impact of nuclear reac-

tors and fuel reprocessing plants. Through the close alliance of the programs in Radiological Sciences and Protection and in Environmental Studies, students are given the opportunity to obtain education, training, and professional development required for positions in the various areas mentioned.

Admission Requirements

A student should have a reasonable preparation including courses in mathematics, chemistry, physics, biology and in nuclear and radiological sciences similiar to the University of Lowell Radiological Health Physics undergraduate curriculum. Since there is no advanced test in the field of Radiological Sciences and Protection, and since various undergraduate backgrounds are suitable for graduate study in the program, students are not required to take the Advanced GRE test. The GRE Aptitude test, however, is required.

Plan of Study

The program allows a student to select courses and a research project consistent with his/her desired area of professional development. Various opportunities for research and professional development are possible through the use of the Energy Center of the University and through cooperative programs with hospitals, nuclear reactor facilities, government laboratories, and other radiation facilities. A research adviser, other than a University of Lowell faculty member, may be approved for the conduct of research at facilities outside the University. A student's program must receive departmental approval. Two research options are available: a thesis or a project. In addition to a core curriculum, a satisfactory master's thesis or project is required.

Thesis Option
Under the thesis option, a student must complete a minimum of 21 credits of formal courses and a minimum of 9 credits of graduate research. The master's thesis generally will consist of a scholarly laboratory or theoretical investigation in the field of Radiological Sciences and Protection. Proposed research must be approved by the program graduate committee. The format for the final written thesis shall conform to the requirements of the Graduate School. Details of proposal and report requirements may be obtained from the Department graduate committee chairman.

Project Option
Under the project option a student must complete a minimum of 27 credits of formal courses and a minimum of 3 credits of graduate research and pass a comprehensive examination. The master's project consists of a scholarly investigation such as a review, report, design, etc., in the field of Radiological Sciences and Protection. The subject of the project must be approved by the student's adviser in advance. The final report must be approved by the program graduate committee and conform to the format specified by the Graduate School.

Oral Defense of Thesis
A thesis committee is appointed to read a student's thesis and to listen to an oral defense presented by the student. In general, the committee will include the thesis adviser and two additional members chosen from the Radiological Sciences faculty and other departments in which the candidate has taken graduate studies.

Comprehensive Examination for the Project Option
Degree candidates electing the project option are required to pass a comprehensive written and/or oral examination administered by the departmental graduate committee. This examination normally will be administered during the semester in which the student completes his course requirements for the M.S. degree. The comprehensive examination may be waived for a student who can document that he has passed Part I of the American Board of Health Physics certification examination.

Core Curriculum
A core curriculum consisting of five courses and research or advanced projects in Radiological Sciences and Protection are required of all students pursuing the Master's degree in Radiological

Sciences and Protection. These core courses are listed below along with other courses offered by the Department for graduate credit. Courses in Nuclear Engineering, Physics and Applied Physics, Environmental Studies, Biology, Mathematics, Meteorology, Chemistry, and others may be selected for graduate credit with the approval of the Department.

Required Core Courses

98-501	Radiation Safety or Control I (or equivalent)	4
98-502	Radiation Safety or Control II (or equivalent)	4
98-505	Radiation Dosimetry	3
98-532	Introduction to Radiation Shielding	3
98-572	Radiation Biology (or equivalent)	3
98-601,602	Graduate Project in Radiation Science and Protection (Project option)	3-6
98-701,702	Graduate Research in Radiological Sciences and Protection (Thesis option)	9-12

Courses of Study

98-501 Principles of Radiation Safety and Control *Skrable* **(3-3)4**
Prerequisite: 80-202 or equivalent
Introduction to radiation protection, including radiation sources, radiation dose and dose measurement, radiation exposure, radiation protection techniques, monitoring methods and instruments, contamination control and waste storage, facility design, hazards analysis, and applied health physics techniques for the safe handling and control of radioactive material, including laboratory.

98-502 Principles of Radiation Safety and Control *Skrable* **(3-3)4**
Prerequisite: 98-501
A laboratory course giving students experience with equipment and practices of current use in the radiation protection field, an extension of 98-501 giving some of the practical aspects of radiation safety and control.

98-505 Radiation Dosimetry *Liuzzi* **(3-0)3**
Sources of radiation exposure; calculations of chronic and acute radiation doses and their effects; internal dosimetry including distribution and elimination of radioisotopes; alpha, beta, gamma, and neutron dosimetry; principles of charge measurement and energy transfer; use and calibration of instruments including solid state dosimeters, ion chambers, and extrapolation chambers.

98-507 Radiation Dosimetry Laboratory *Staff* **(0-3)1**
Prerequisite: 98-505 currently.
(Not offered every year)
Laboratory experience coordinated with lecture sequence in 98-505.

98-508 Environmental Toxicology and Epidemiology *Harris* **(3-0)3**
Prerequisite: Graduate student with science background or permission of Instructor.
(Offered in odd-numbered years)
Study of the systems of the body with respect to the sites and modes of action by various toxic agents. Discussion of procedures for evaluation of

toxicity of radioactive and non-radioactive agents. Determination of TLV and LD50 values. Review of status of current epidemiology studies of effects of radiation and other toxic agents. Discussion of occupational environments with respect to standards, control measures, and current problems. Review of standards for protection of the environment and the general public.

98-510 Environmental Toxicology Laboratory *Harris* **(0-3)1**
Prerequisite: 98-508 concurrently.
Laboratory experiments on the effects of toxic agents on plant and animal systems with emphasis on radiation and air pollution. (Offered odd-numbered years)

98-513 Environmental Monitoring and Surveillance *Staff* **(3-0)3**
Prerequisite: 98-502
Sources and types of natural and man-made environmental radioactivity; meteorological, hydrological and ecological considerations in the transport of radionuclides released to the environment, ecological pathways important in the consideration and estimation of resulting doses or in the selection of environmental sampling media; objectives and design of pre-operational, operational and emergency monitoring programs; sampling and analysis programs for specific radionuclides and external radiation sources; analytical equipment and procedures and limits of detection for specific radionuclides; design of an environmental laboratory and emergency monitoring vans for nuclear power stations.

98-514 External Radiation Dosimetry *Chabot* **(3-3)4**
Provides a review and gives state of the art information in this important area of radiation protection. Information presented is reinforced through laboratories demonstrations and problem solving sessions. Includes a review of radiation quantities and units; sources of external radiation exposure; calculation of receptor free radiation quantities for different geometry sources; beta, gamma, and neutron dosimetry; principles of charge measurement and energy transfer; use and calibration of instruments including solid state and film dosimeters, ion chambers, and extrapolation chambers; calibration sources; accident dosimetry; recommendations of standard setting organizations; and regulatory requirements.

98-515 Internal Radiation Dosimetry *Skrable* **(3-0)3**
Provides a review and gives state of the art information in this important radiation protection area. Information presented is reinforced through demonstrations and problem solving sessions. Includes a review of the applicable physiological models for standard man; sources of internal radiation exposure; a comparison of the 1959 ICRP 2 and the 1978 ICRP 30 reports, recommendations and models, kinetics equations for calculating the instantaneous burden, atoms absorbed into the blood, excreta, and cumulated activities of parent and daughter radionuclides in various organs, tissues, and compartments of the body; calculation of specific absorbed energies, 50 year dose equivalent commitment and values weighted by cancer and hereditary disease risk, Annual Limit Intakes (ALI), and Derived Air Concentrations (DAC); guidance relative to the interpretation of body measurements and bioassay data in terms of investigation levels and appropriate actions at various levels; recommended frequency for body burden measurements and bioassays based upon minimum detectable activities, investigation levels, and potential for ex-

posure; accident internal radiation dosimetry; recommendations of standard setting organizations; and regulatory requirements.

98-516 Data Reduction for Radiological Sciences and Protection *Skrable* **(3-0)3**

Provides the development and use of fundamental statistical concepts applicable to data reduction and error analyses. Concepts and relationships are reinforced by the presentation of applications in the field of radiological sciences and protection and through the solutions of many example problems. Concepts and applications presented in the course may include: the fundamental statistical concepts of errors, means, variance, and standard deviations of parent and sample populations; permutations and combinations; integral, discrete and differential distribution functions including the binomial, Poisson, Gaussian, and Lorentzian distributions; applications of binomial discrete probability function and a general kinetics equation to the estimation of populations of radioactive atoms through sampling and counting experiments; propagation of errors; variance in sample, background, and net counts and in counting rates; optimum distribution of background and sample counting intervals; optimum counting interval for estimation of population of atoms of a short lived radionuclide; minimum detectable activity and lower limit of detection of counting systems; chi square and other statistical tests of the operability of counting systems, tests of distributions, fitting functions, and a-priori assumption of population variance; correlation probability; estimation of parameter values of fitting functions by method of least squares; and χ^2 and F test of the goodness of fit.

98-522 Environmental Radiation and Nuclear Site Criteria *Harris* **(3-0)3**

Prerequisite: Radiological Science 98-501 or equivalent

Sources of radioactive waste and waste treatment; internal dosimetry, maximum permissible concentrations; distribution of radioactivity and the environment and the significance of releases to the air, aquatic and terrestrial ecosystems; design and operation of environmental surveillance programs around nuclear facilties, reactor site criteria, licensing, regulations, credible accidents, meteorological considerations, normal and abnormal operations, environmental impact of nuclear reactors.

98-525 Medical Health Physics *Staff* **(3-0)3**

Sources of radiation and radioactive material associated with the medical applications of nuclear medicine, X-Ray diagnosis, and radiation therapy; shielding of X-Ray and radiation therapy facilities; survey and monitoring instruments and procedures; personal monitoring; federal and state regulations; waste disposal; and clinical support role of health physicist.

98-532 Introduction to Nuclear Radiation Shielding *Liuzzi* **(3-0)3**

Prerequisite: Permission of Instructor, Advanced Calculus and Radiological Sciences graduate student or equivalent

Interaction of neutrons, gamma rays and charged particles with matter; buildup factors; shielding of point, surface, and volume sources; shielding design factors in reactor and accelerator operation.

98-534 Introduction to Radiation Shielding Laboratory *Staff* **(0-3)1**

Prerequisite: 98-532 concurrently.

(Not offered every year)

Laboratory coordinated with 98-532 with applications to health physics problems.

98-541 Radioisotope Techniques *Harris* **(3-0)3**
Prerequisite: Biology senior or equivalent background
A course for students and staff designed to acquaint them with the theory and use of radioisotopes and the principles and operation of radiation counting systems. Lecture sessions on topics related to biological effects of radiation exposure, safe use of radiation sources, radiation protection techniques and procedures, and design of radiation facilities.

98-543 Radioisotope Techniques Lab I *Harris* **(0-3)1**
Prerequisite: 98-541 concurrently or equivalent
Laboratory experience in tracer techniques and appropriate use of various types of laboratory counting instruments.

98-551 Introduction to Electronic Product Radiation *Staff* **(3-0)3**
Prerequisite: 98-501
The theoretical and applied aspects of the generation, measurement, and uses of radiant energy from electronic products whose emissions span the entire electromagnetic spectrum; ultrasonic energy emitted by electronic products, biological effects, standards of protection and control, and consequences and intent of Public Law 90-602.

98-561 Special Topics in Radiological Sciences *Staff* **(3-0)3**
Prerequisite: Radiological Sciences and Protection graduate student
This course is used to provide students with current information on topics of interest to graduate students in radiological Sciences and Protection. Course may include preparation and presentation of lectures applicable to training of health physics technicians. Topics covered may vary from year to year. Topics are announced prior to registration.

98-562 Special Topics in Radiological Sciences *Staff* **(3-0)3**
Prerequisite: See 98-561

98-563 Introduction to Radiation Chemistry *Alexander* **(3-0)3**
Prerequisite: Permission of Instructor
(Not offered every year)
A study of the interaction of all types of ionizing radiation with matter and the resulting radiation-induced chemical reactions; excitation, ionization, and free radical formation and recombination.

98-572 Radiation Biology *Harris* **(3-0)3**
Prerequisite: 81-252, 98-541 or equivalent
A study of the interactions of radiations with living systems. The effects of ionizing radiation at the molecular, cellular and organismic levels. The acute and latent effects in whole animals and the modification of radiation exposure by physical, chemical and biological factors.

98-601 Graduate Project in Radiological Sciences and Protection *Staff* **(0-10)3**

98-602 Graduate Project in Radiological Sciences and Protection *Staff* **(0-10)3**
Prerequisite: Completion of a minimum of one semester of graduate study in Radiological Sciences and Protection and approval of faculty advisor
This course provides credit for a project done by master's degree candidates.

98-611 Seminar in Radiological Sciences *Liuzzi* **(1-0)1**

98-612 Seminar in Radiological Sciences *Liuzzi* **(1-0)1**
Individual presentations by students and the staff of advanced topics, original research or journal articles. Given when the demand is sufficent.

98-701 Graduate Research in Radiological Sciences and Protection *Staff* **(0-10)3**
Prerequisite: Completion of a minumum of one semester of graduate study in Radiological Sciences and Protection and approval of faculty adviser.
This course provides credit for research done by master's degree candidates.

98-702 Graduate Research in Radiological Sciences and Protection *Staff* **(0-10)3**
See 98-701

98-751 Advanced Projects in Radiological Sciences *Staff* **(0-10)1-3**
An opportunity for individual study under the direction of a staff member of topics related to radiological sciences and protection.

ACADEMIC CALENDAR 1981-1982

(Tentative)

FALL SEMESTER

Registration for New Students (Enrolled students pay late fee)	September 3, 4
Classes Begin	September 8
Last Day to Change Enrollment Status (i.e., add, drop courses, etc.)	September 21
Last Day for Clearance Forms for Summer Degree	September 25
Columbus Day — University Closed	October 12
Monday Class Schedule on Tuesday	October 13
Advising Period for Spring Registration	November 2-13
Veterans' Day — University Closed	November 11
Registration for Spring Semester	November 18-20
Thanksgiving Recess Begins — 4:00 P.M.	November 25
Classes Resume	November 30
Last Day to Drop Classes with W	December 7
Classes End	December 15
Final Examinations Begin	December 16
Last Day of Final Examinations — Semester Ends	December 23
Last Day to Submit Clearances for Fall Degree	December 31

SPRING SEMESTER

Registration for New Students (Enrolled students pay late fee)	January 21, 22
Classes Begin	January 25
Last Day to Change Enrollment Status (i.e., add, drop courses, etc.)	February 5
Washington's Birthday — University Closed	February 15
Monday Class Schedule on Tuesday	Febuary 16
Spring Recess Begins — 6:00 P.M.	March 12
Classes Resume	March 22
Advising Period for Fall Registration	April 5-16
Patriot's Day — University Closed	April 19
Registration for Fall Semester	April 21-23
Friday Schedule on Thursday	April 29
University Day (Spring Carnival) No Classes	April 30
Last Day for Students to Drop Course with W	May 6
Classes End	May 13
Final Examinations Begin	May 14
Last Day to Submit Clearances for Spring Degree	May 14
Last Day of Final Examinations — Semester Ends	May 21
Commencement	May 29

ACADEMIC CALENDAR 1982-1983

(Tentative)

FALL SEMESTER

Registration for New Students (Enrolled students pay late fee)	September 2, 3
Classes Begin	September 7
Last Day to Change Enrollment Status (i.e., add, drop courses, etc.)	September 20
Last Day for Clearance Forms for Summer Degree	September 24
Columbus Day — University Closed	October 11
Monday Class Schedule on Tuesday	October 12
Advising Period for Spring Registration	November 1-12
Thursday Class Schedule on Wednesday	November 10
Veterans' Day — University Closed	November 11
Registration for Spring Semester	November 17-29
Thanksgiving Recess Begins — 4:00 P.M.	November 24
Classes Resume	November 29
Last Day to Drop Classes with W	December 3
Classes End	December 15
Final Examinations Begin	December 16
Last Day of Final Examinations — Semester Ends	December 23
Last Day to Submit Clearances for Fall Degree	December 31

SPRING SEMESTER

Registration for New Students (Enrolled students pay late fee)	January 20, 21
Classes Begin	January 24
Last Day to Change Enrollment Status (i.e., add, drop courses, etc.)	February 4
Washington's Birthday — University Closed	February 21
Monday Class Schedule on Tuesday	Febuary 22
Spring Recess Begins — 6:00 P.M.	March 18
Classes Resume	March 28
Advising Period for Fall Registration	April 4-15
Patriot's Day — University Closed	April 18
Friday Schedule on Thursday	April 28
Registration for Fall Semester	April 20-22
University Day (Spring Carnival) No Classes	April 29
Last Day for Students to Drop Course with W	May 6
Classes End	May 12
Last Day to Submit Clearances for Spring Degree	May 13
Final Examinations Begin	May 13
Last Day of Final Examinations — Semester Ends	May 20
Commencement	May 28

ACADEMIC CALENDAR 1983-1984

(Tentative)

FALL SEMESTER

Registration for New Students (Enrolled students pay late fee)	September 1, 2
Classes Begin	September 6
Last Day to Change Enrollment Status (i.e., add, drop courses, etc.)	September 19
Last Day for Clearance Forms for Summer Degree	September 23
Columbus Day — University Closed	October 10
Monday Class Schedule on Tuesday	October 11
Advising Period for Spring Registration	November 1-11
Veterans' Day — University Closed	November 11
Registration for Spring Semester	November 16-18
Thanksgiving Recess Begins — 4:00 P.M.	November 26
Classes Resume	November 28
Last Day to Drop Classes with W	December 5
Classes End	December 15
Final Examinations Begin	December 16
Last Day of Final Examinations — Semester Ends	December 23
Last Day to Submit Clearances for Fall Degree	December 30

SPRING SEMESTER

Registration for New Students (Enrolled students pay late fee)	January 19, 20
Classes Begin	January 23
Last Day to Change Enrollment Status (i.e., add, drop courses, etc.)	February 2
Washington's Birthday — University Closed	February 20
Monday Class Schedule on Tuesday	Febuary 21
Spring Recess Begins — 6:00 P.M.	March 16
Advising Period for Fall Registration	April 1-17
Patriot's Day — University Closed	April 16
Registration for Fall Semester	April 18-20
Friday Schedule on Thursday	April 26
University Day (Spring Carnival) No Classes	April 27
Last Day for Students to Drop Course with W	April 30
Classes End	May 10
Final Examinations Begin	May 11
Last Day to Submit Clearances for Spring Degree	May 11
Last Day of Final Examinations — Semester Ends	May 18
Commencement	May 26

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UNIVERSITY OF LOWELL
North Campus

1 Ball Center
2 Costello Gym
3 Cumnock Hall
4 dormitories
5 Eames Hall
6 Engineering
7 Falmouth
8 Kitson
9 Library, Alumni/Lydon
10 Nuclear Center
11 Olney
12 Olsen
13 Pasteur
14 power plant
15 Research Foundation
16 Southwick Hall
17 Smith Hall
18 Student Union

South Campus

1 Allen House
2 Coburn Hall
3 Concordia Hall
4 dining hall
5 Dugan Hall
6 Durgin Hall
7 Mahoney Hall
8 O'Leary Library
9 power plant
10 Student Union
11 Weed Hall
P parking

Merrimack River
Fox Student Union and dormitories
Research Foundation
Dracut
VFW Highway
University Ave
Riverside St
Graduate School Annex
INFIRMARY
Northern Canal
St Josephs Hospital
French St Extension
Merrimack St
Lowell Museum
U.S. POST OFFICE
Rt 38
Methuen
Lawrence
Rt 110
Lowell General Hospital
Varnum Ave
Pawtucket St
Fletcher
Salem St
JFK Civic Center
City Hall and Library
Lowell High School
Arcand Dr
Lowell Memorial Auditorium
John St
Bridge St
UL Boat House
Wannalancit St
School St
Bowers St
north common
Adams St
Market St
Whistler House
St John's Hospital
Varney St
Butterfield St
Cross St
Wilder St
Broadway
Fletcher St
Registry Motor Vehicles
Dutton St
Central St
Rt 133
Andover St
Church St
Mansur St
Concord River
Pawtucket Canal
Middlesex St
Appleton
south common
Westford St
Chelmsford St
Thorndike St
Train Station
YMCA
Thorndike St Exit 5N
Lowell Connector comes off rt 3 Exit 30 N

	Location	Tel.	Ext. #
Affirmative Action Office	Lydon 1st floor	North	2379
Alumni Office	Lydon 2nd floor	North	2396 454-6335
Bookstore(s)	Student Union Southwick	South North	2452 459-4567 2248 454-1331
Business Office (Billing-Payments)	Dugan 1st floor	South	2423, 2425, 2428
Computer Center	Olsen 109	North	2498, 2594
Counseling Center	S.V.B.-South	South	2390
Evening School	Cumnock	North	2221, 2228
Financial Aid	Dugan 200	South	2411
Graduate School	Cumnock	North	2206, 2207
Libraries	Lydon O'Leary	North South	2374, 2377, 2378 2483, Reference desk: 2485
Media Center	Lydon O'Leary	North South	2385, 2384 2487
Energy Center	Pinansky	North	2237
Placement Offices	Fox Hall	North	2333, 2334
Registrar (transcripts)	Southwick 223	North	2214, 2220
Summer Session	Cumnock	North	2244

UNIVERSITY OF LOWELL
GRADUATE SCHOOL
ONE UNIVERSITY AVENUE
LOWELL, MASSACHUSETTS
01854

THIRD CLASS MAIL